Are Small-scale Fishers Profit Maximizers?: Exploring Fishing Performance of Small-scale Fishers and Factors Determining Catch Rates

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ABSTRACT

Exploration of the concepts of "profit maximizer" and "skipper effect" was undertaken using empirical data from small-scale fisheries in Yucatán, México. Fishers from the three communities studied exploit the same fishing resources and are constrained by similar regulations and environmental conditions. A comparative analysis was undertaken based on catch rates and the generation of a fishing performance index. General Lineal Models (GLM) were employed to identify variables associated to catches obtained by fishers in all communities. The results show differences among and within communities in catch profiles. We conclude that not all fisher tend to maximize their catches even though some fishers appear to be more efficient than others. In one community, differences between the more efficient fishers and the 'average' were tenfold, in other community fishers were more homogeneous. Variations in catch and landed values were associated mainly with the number of trips undertaken within a fishing season in all communities. In addition, in Dzilam Bravo, fishers' experience, boat size, and motor power were also associated with catch variation. Hence, a mix of several elements, seem to determine catch rates in the case of small-scale fishers with important contribiution due to fishers choices regarding the frequency of trips they undertake. We discuss the implication of using fishing performance index as an indication of the level of exploitation of fisheries and implications for policy design.

KEY WORDS: Catch rate, Fishing performance, fisheries management, Yucatan

Are Small-scale Fishers Profit Maximizers? : Exploring Fishing Performance of Small-scale Fishers and Factors Determining Catch Rates

El concepto de "maximizador de ganancias" y "efecto del pescador" se exploran en un estudio usando datos empíricos de pesquerías de pequeña escala en Yucatán, México. Los pescadores de las tres comunidades estudiadas explotan los mismos recursos pesqueros y están limitados por las mismas regulaciones y factores ambientales. Se realizó un análisis comparativo entre estas comunidades a través de la generación de un índice de eficiencia pesquera y con el uso de modelos lineales generalizados (MLG) para identificar las variables asociadas a sus tasas de captura. Los resultados muestran diferencias entre las comunidades en sus perfiles de capturas. Concluimos que no todos los pescadores tienden a maximizar sus capturas, aún cuando algunos parecen ser más eficientes que otros. En una comunidad la diferencia entre los pescadores más eficientes y los "promedio" fué 10 veces más alta, mientras en otra comunidad los pescadores parecen ser más homogéneos. Una mezcla de factores parece determinar las tasas de captura de los pescadores de pequeña escala con un importante componente asociado a las decisiones de los pescadores sobre los viajes que realizan. La experiencia de pesca del pescador y el poder del motor empleado resultaron variables significativas asociadas a las capturas y el bio-valor en dos comunidades. Discutimos en este estudio las implicaciones de considerar índices de eficiencia como indicadores del nivel de explotación en pesquerías de pequeña escala a fin de proveer elementos en políticas de manejo pesquero.

PALABRAS CLAVES: Tasas de captura, índice de eficiencia pesquero, manejo pesquero, Yucatán

INTRODUCTION

It has been reported that distribution of the catch among fishers can reveal trends of fishing performance of fishers as fishing is not only a commercial activity, but also a very uncertain and competitive one, where fishing practices are associated not only with biological, technological and environmental factors, but also with the behavioral practices of the fishers (Gaertner *et al.* 1999, Holland *et al.* 1999, Tingley *et al.* 2005). Furthermore, the way individuals perform will be reflected in the distribution of the catches among those sharing the resources (Hilborn 1985, Abrahams and Healey 1990). This variability has been associated with several factors:

i) Technological improvements of the boats or gear modifications increasing catch power and a reduction in searching time (Pálsson and Durrenberger 1982, Christensen 1993),
ii) Fisher skill (Forman 1967, Gaertner *et al*. 1999), and
iii) Bio-geographical conditions that affect fishing resources'behavior and furthermore define where and how fishers operate (Healey and Morris 1992, Puga *et al*. 1996, Salas *et al.* 2004).

In addressing the determinants of fishing performance, fisheries scientists have given more attention to changes in the distribution of fishing effort and catchability due to technological modifications over the long-term, than to determinants of changes in catch rates within a fishing season. For example, special attention has been paid to identifying a standardized 'boat type' in order to standardize fishing effort when defining management schemes (Clark and Kirkwood 1979, Hilborn and Ledbetter 1985). However, differences in catchability can introduce bias in the definition of production functions and stock assessment (see Ruttan and Tyedmers 2007, and references therein). Durrenberger (1993) states that it makes little sense to try to control fishing pressure in a fishery solely by focusing on capacity in terms of the number of boats and fishers, if other variables, such as skill levels, significantly influence the catch. According to Ruttan and Tyedmers (2007), not all skippers are utilizing the technology available to them to its full potential. Hence, both capacity and behavioral components may be present, and hence a combination of management strategies needs to be considered when defining fisheries policies.

Looking at the behavioural component has been done in recreational fisheries through the analysis of seasonal distribution of the catch in the short-term based on estimation of performance indexes. This has enabled comparisons of patterns of behavior among anglers, and facilitated evaluations of the impacts of regulatory schemes upon fishers (Baccante 1995). In commercial fisheries, approaches considering economic indicators have been common (Clark and Kirkwood 1979, Robinson and Pascoe 1997, Boncoeur *et al*. 2000, and references therein), although the influence of seasonal changes on individual fishing patterns has been acknowledged (Cove 1973, Sampson 1992, Sullivan and Rebert 1998, Salas *et al*. 2004).

One of the problems to address individual fishing patterns is the limitation to have access to detailed information on catch records at individual level. Aggregation of information can shadow individual patterns and generate biased results. In this study, we explore the concepts of "profit maximizer" based on empirical data from small-scale fisheries in Yucatán, México. Fishers from the communities studied exploit the same fishing resources and are constrained by similar regulations and environmental conditions, and we were able to gather daily catch data which allow the generation of a fishing performance index and undertake a comparative analysis and explore the contribution of certain variables on the catch rates of small-scale fishers within a fishing season.

METHODS

Data Sources

One of the problems to approach fishing patterns in the short term is to be able to analyze catch data at a fine scale, e.g detailed record of catches by fisher and day. We were able to obtain the log books of three fishing cooperatives in Yucatan, Mexico that include a data set comprising daily catch by fisher from 20,000 individual fishing trips carried out by 377 fishers between 1992 and 1993 (Figure 1). Data were discriminated by species (lobster, grouper, octopus plus other demersal species) and included price per each species paid to fishers when landing. Catch (kg) and effort was estimated from this records, defining daily trips as the unit of fishing effort. Given the fact fishers get paid base on those records its reliability is high, and can be obtained at low cost. In addition, information regarding age and fishers' experience in this activity was obtained from the same fishing cooperatives.

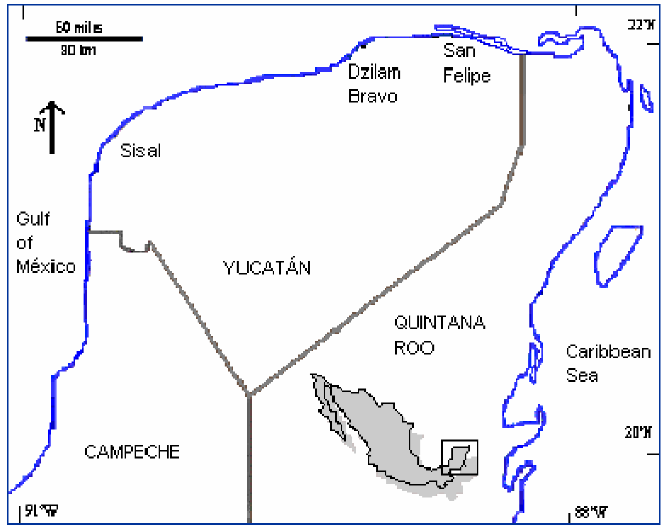

Figure 1. Study area. Fishing communities of the Yucatan coast.

Fishers' Performance Index

On a daily basis, small-scale fishers tend to evaluate the fishing performance of their peers as a means to assess and compare their own performance (R. López Pers. comm). Hence, we define a performance index for purposes of comparison according to the modified function employed by Hilborn and Ledbetter (1985) to evaluate performance of boats. The measure of fishers' performance is defined as follows:

$$CP_{kzt} = \frac{1}{n}\sum_{n=1}^{N}(C_{kznt} - \bar{C}_{znt}) \qquad (1)$$

Where:

N is the number of trips per month t, n the daily trips of individual fisher from community z, C_{kzn} is the total catch (including all species) of fisher k, from community z, in trip n, at month t, and $\bar{C}_{zt}$ is the average catch per month of all fishers in the respective community.

As species vary considerably in price ($28 Dlls kg for lobster vs. $3-4 Dlls kg for other species), catch composition varies notably in terms of value. Thus, we consider both catch and monetary value (landed value) in the estimation of alternative forms of the performance index, e.g. the rate of return for fishers. This performance index can be measured hence in terms of catch or money, depending on what goal the fishers are trying to achieve (Robinson and Pascoe 1997, Salas and Gaertner 2004).

In the case of landed value, the performance index (LVP) is obtained by the substitution of landed value (*LV*) instead of catch (*C*) in equation (1). The LV was calculated as the product of catch times the price of the respective specie and then summed up by trip before estimating the performance index.

$$LVP_{kzt} = \frac{1}{n}\sum_{n=1}^{N}(LV_{kznt} - \overline{LV}_{znt}) \qquad (2)$$

Once performance in terms of catch and landed value was estimated for each fishing community, comparison between and within fishing communities of this index was carried out. We defined three categories of the performance index for comparison purposes: below average (*BA*), average (*A*), and above average (*AA*). To ensure systematic definition of these categories, we defined them according to the percentiles of the performance distribution by category as follows:

i) Below Average (*BA*): Up to 30%,
ii) Average (*A*): Between 30-60%,
iii) Above Average (*AA*): Over 60%.

This selection was defined after testing different combinations within different ranges of the percentiles until the differences among the categories were statistically significant in each community (Kruskal-Wallis test $p < 0.05$; Siegel and Castellan 1988). It is worth stressing that the scale proposed here was made only for purposes of comparison. The aim was to evaluate differences among groups having as a reference point, in this case an 'average value' as the fishers compare themselves with their peers. That does not mean that an 'average fisher' exists or that values above or below the average have a positive or negative meaning.

Variables Associated to Performance

In informal conversations about what fishers consider the most important factors that define their performance when fishing, they mentioned: types of gear, boats, number of days fishing, luck, fishers' experience, and knowledge. Based on the fishers' statements and literature review, we applied GLM to identify the factors that contribute to the variability of catch rate or landed value per trip in each community. Hence for this analysis we assumed then that catch (C) and landed value (LV) are affected by the following factors:

Choice variable — Number of trips per fisher undertaken in a month and species targeted in a given trip. The target species predictor was defined as a dummy with five levels: grouper, lobster, octopus, others and 'combination of species'. Grouper was selected as the indicator category (*IC*) - takes zero value-- (von Eye and Schuster 1998). As prices affect landed value, the categorical variables defined for target species were based on the proportion of each species in terms of weight and dollars for catch and landed value, respectively.

Individual attributes — Boat length, engine power, and fishers experience were considered here. Only in a very few cases, information about other attributes of the boats such as the storage capacity, width, age of the boat and motor was available; being incomplete, these variables were not included in the analysis. Boats in Sisal are all the same size, but motor power differs thus boat size was eliminated from the variables for this community from this analysis (since a regression is not possible with no contrast in the data).

Seasonal component — This component defined as season was related with environmental conditions. A dummy variable with three levels was used to define this component such as apply in tropical areas: windy season (November to February), dry season (March - June) and rainy season (July - October). Windy season was selected as the indicator category of the dummy.

We used a data matrix of daily catch summarized by individual fisher and undertook the analysis separately for each community. We included both numerical and categorical variables as the explanatory variables. The criteria for deciding which variables would be included in the analysis from the initial set proposed were based on: theoretical importance, statistical significance, and potential of the variable to be compared under the same or different design for the future (Achen 1982).

As a general linear model was chosen for this analysis, logarithmic transformation was applied to the numerical variables when required. For instance, only fishing' experience, and the number of trips in Sisal fit a normal distribution. In all communities, catch, landed value, boat size and engine power were transformed and a normality test was carried out afterwards using a Normal probability plot (Q-Q plot) (Norusis 1997).

We selected the final model based on the relative significance of each coefficient compared with those from the prior models. We used the ordinary least square criterion (OLS) for parameter estimation (Norusis 1997, vonEye and Schuster 1998). As indicators of goodness of fit, a Partial F-test statistics, the standard error of the estimate and the adjusted coefficient of determination (R^2) were considered (Achen 1982, vonEye and Scuster 1998).

RESULTS

Performance index

Based on the performance categories in terms of catch and landed value, over 50% of the fishers in Sisal fall into the 'average' category which define them as a more homogeneous group compared with the other communities (Figure 2a and 2b) with less of 20% of fishers with a rate above average. In San Felipe and Dzilam Bravo a mix of fishers with high, medium, and low performance were observed when the catch performance was evaluated.

However, the patterns change slightly when landed value was considered (Figure 2b). Under this profile, more fishers from Dzilam Bravo appear to perform better than the rest. Fisher may use different strategies to achieve a given catch or income, hence high performance could result of three possible options when it comes to revenues: a) fishers catch high volumes of a species of low value, b) small but significant amount of profitable species, or c) a combination of both. The later seems more common among small-scale fishers in the region.

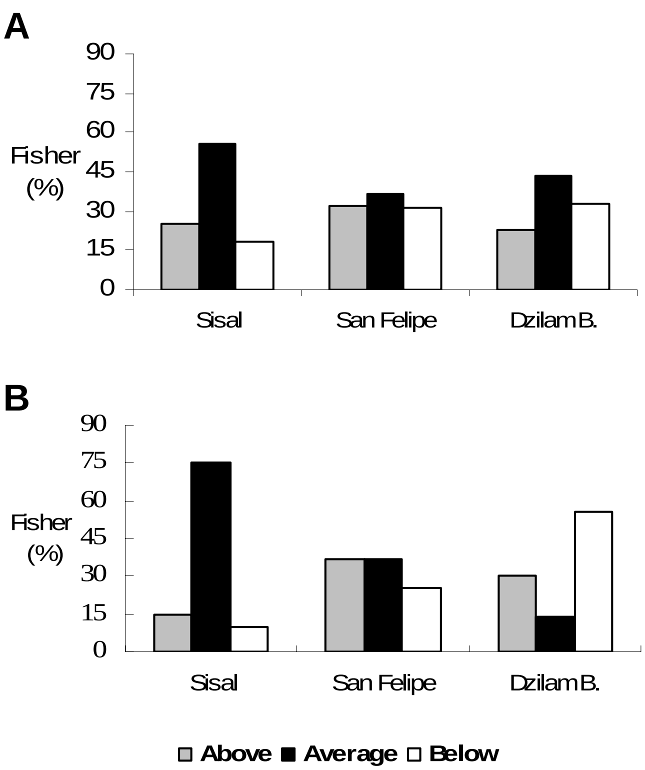

Figure 2. Performance index for a) catch and b) landed value for three fishing communities in the Yucatan coast, Mexico, based in the following categories: BA (below average), A (average), and AA (above the average).

Significant differences among all communities were evident when comparing the monthly patterns (Kruskal–Wallis test, p = 0.05). In all cases, the range of variation for the index in terms of catch was smaller during the closed seasons for lobster and octopus than during the fishing season of both species (mid year towards December). This pattern is more drastic in Dzilam Bravo than in the other communities were the performance index in catch and revenues (confidence limits at 95%) exhibit a wider range of variation (Figure 3).

When we contrasted the performance among fisher within their own community we found significant differences among fishers in all communities (Kruskal–Wallis test, p = 0.05). We observed differences in the Catch per Unit of effort (CPUE) among those fishers in the range above average in Dzilam Bravo and San Felipe, but not in Sisal. The same apply when evaluated in terms of money – defined here as fishing efficiency- where the mean range was wide for Dzilam Bravo, e.g, catch of fishers above the average (AA) where ten fold higher than those on the average (A) (Table 1).

Even though fishers range between 20 and 50 years of age, fishing experience varies from the lowest in Sisal to the highest in Dzilam Bravo. The former are fishermen that come from rural areas and got involved into fishing through governmental programs. Those in Dzilam Bravo have more experience in the fishing activity and also some of them have larger boats. This could be related with the lowest CPUEs observed in Sisal compared with the others especially Dzilam Bravo (Table 2).

Factors Defining Catch and Revenues

Results from the regression model are depicted in Table 3. Normal distribution of the residuals confirmed that the linear model after transformation was appropriate for this analysis. Only variables with significant coefficients were included in the table (p = 0.01). The analysis indicates that catch rate and landed value per trip were strongly related to the number of trips, and all other variables have much lower coefficients. In all cases, coefficients for the 'number of trips' variable was never lower than 0.5. This result makes sense as small-scale fisheries are characterized by labor intensive inputs, hence choice of fishermen regarding frequency of the trips they undertake have an important contribution on catcha rates.

In Sisal, only the coefficients for trips and season (weather) were significantly different from zero. That is, catch rate and landed values per trip were related mainly to (1) how often fishers went fishing and (2) the extent to which they were limited or favored by seasonal weather conditions. Since the default or reference category for the environmental dummy variable was the windy season, and for Sisal, the rainy season (July-September) and the dry season (March-Jun) have a negative sign and a positive sign, respectively, this implies that performance is worse in the rainy season and better in the dry season relative to the windy season. Wind imposes limitations on fishing such as (a) increased turbidity, which affects the lobster fishery given the fishing method (diving), or (b) sudden changes in wind direction ("Chikinic"), which can represent a real treat to the safety of fishers. Strong winds coming from the north ('Nortes') can limit and even shut down the fishing activity for several days.

Table 1. Range of variation of catch per unit effort (CPUE) and fishing efficiency (FE) by performance category.

Community	Performance category	CPUE (kg/trip)		Fishing efficiency ($/trip)	
		Max	Min	Max	Min
	BA	58.5	3.6	100.5	25.7
Sisal	A	60.0	17.9	181.6	36.3
	AA	94.8	25.2	139.8	44.5
San Felipe	BA	49.8	2.4	187.9	4.23
	A	72.4	7.3	373.1	19.5
	AA	256.4	28.2	589.1	40.9
Dzilam B.	BA	62.6	1.3	404.4	2.2
	A	119.6	1.4	738.7	9.0
	AA	1679.0	55.3	2532.3	48.5

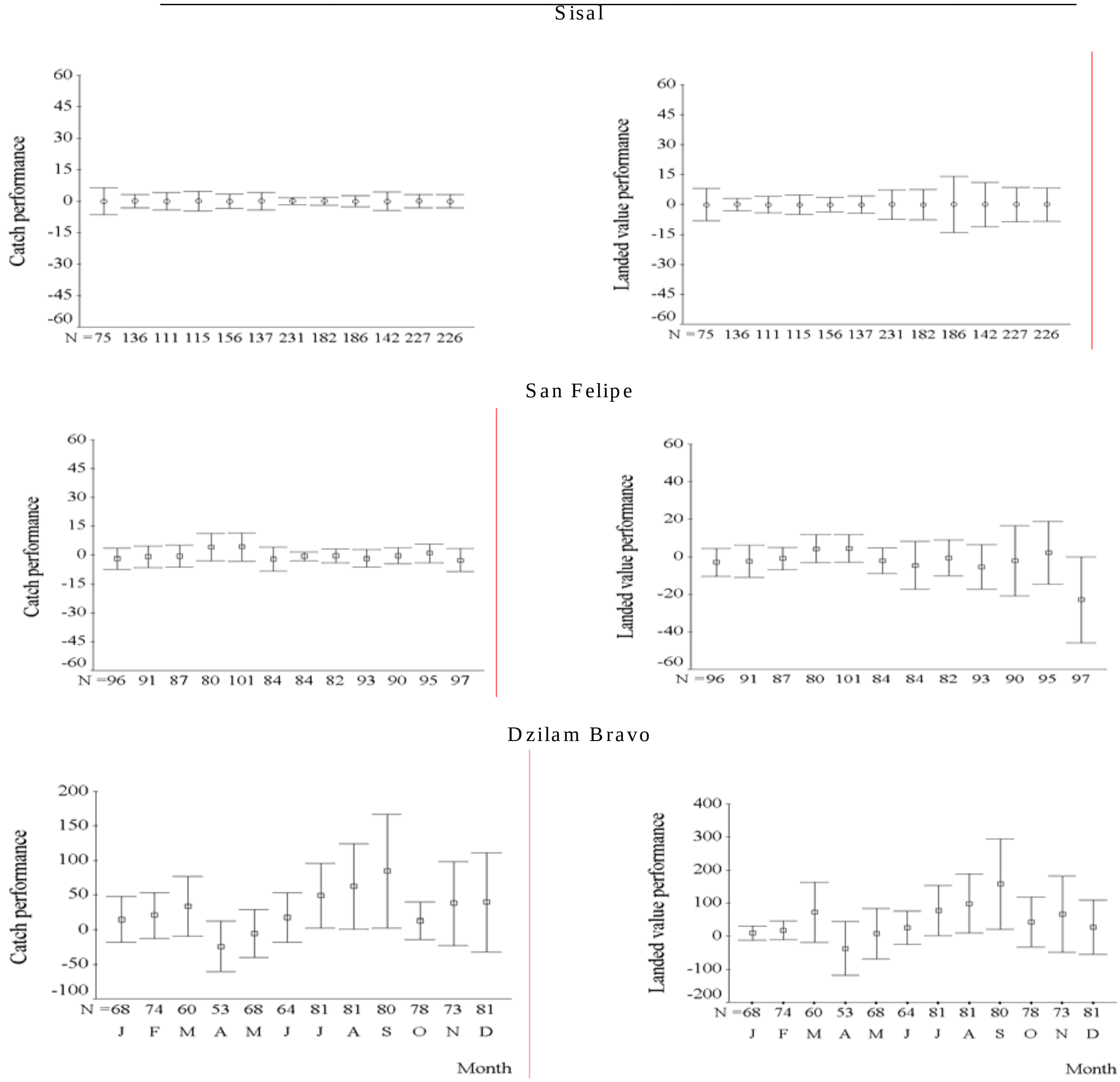

Figure 3. Monthly variation of fishing performance in terms catch (right panels) and landed value per trip (left panels). The values of ***N*** shown below the horizontal axis indicate the number of fishers active in each month. The confidence intervals were estimated at 95%.

Table 2. Mean values and range of variation of attributes of fishers and boats for different performance' categories

Community	Performance category	Fishers' experience (years)	Fishers' age (years)	Boat size (m)	Engine power (HP)
	BA	4	36	7.6	55
Sisal	A	4	35	7.6	55
	AA	4	33	7.6	60
	Range	1-8	21-45		55-60
San Felipe	BA	7	32	7.5	44
	A	7	33	7.5	47
	AA	7	33	8.6	55
	Range	1-18	21-56	7.5-8.6	20-60
Dzilam B.	BA	15	33	7.6	44
	A	12	34	7.8	55
	AA	15	35	10	60
	Range	1-36	15-50	7-10	20-60

Table 3. Standardized coefficients from multiple regression analysis (MRA) for catch and landed value per trip in three coastal communities. Reference category for dummy in species is grouper and for season is windy season. p = 0.01 (N/A= Not applicable)

	Catch/ trip			Landed value per trip		
Variable	Sisal	San Feli-pe	Dzilam Bravo	Sisal	San Feli-pe	Dzilam Bravo
Constant	5.854	-4.72	-2.34	6.32	-6.57	-0.71
Fishers' experience			0.23			0.17
Fishers' age		-0.14			-0.14	
Ln(Boat size)	N/A	0.14	0.13	N/A	0.14	0.07
Ln(Motor power)		0.16	0.15		0.15	0.15
Ln(Trips)	0.56	0.77	0.70	0.62	0.59	0.56
Species:						
Lobster						0.09
Octopus			0.10			0.07
Others			-0.09		-0.06	-0.11
Season:						
Rainy	-0.51	-0.18	-0.23	-0.39	0.08	-0.21
Dry	0.21	-0.15	-0.17	0.17		0.19
R^2	0.70	0.68	0.66	0.53	0.70	0.62

In San Felipe, catch rates were positively related to the number of trips and the physical attributes of the vessel (size and power), but had little relation to the species fished, and a mixed relation to the seasonal weather. In contrast to Sisal, in this case, rain has a positive impact on the dependent variable landed value. This period comprises the opening of the lobster and octopus season where high catches of these resources are common in the community. In addition, fishers' age was a significant variable in this case. This may be related to the fact that lobster fishers require strong diving skills to fish with hookah. Some fishers argue that the younger the fisher the more willing he is to take challenges while diving. Durrenberger (1993) found similar results in a fishery in Mississippi where younger and more skilled fishers were more willing to "push harder" while fishing.

In Dzilam Bravo, boat size, number of trips, and engine power were significant variables that contribute to variability of catch and landed value. Fishers' experience was also significant in this case. In this community there is a wider range of boat size and motor power, and fishers have long tradition fishing. Contrary to the other communities in Dzilam Bravo target species with a low coefficient were also significant variables.

It is necessary to note that, in contrast to other applications of GLP (prediction), the analysis performed in this study used the tool exclusively for hypothesis testing and not to generate predictive models.

DISCUSSION AND CONCLUSIONS

In fishing, people compete for limited resources and it would be expected that they will naturally try to obtain the best from their operations, not only in terms of catch and landed value, but also in terms of their reputation and position in the community. For instance, Cove (1973) reports that some captains in Newfoundland, Canada, do not give too much attention to their total catches as long as they are higher than those of other skippers. Miller and Maanen (1979) also state that fishers, like boats, acquire a reputation on the basis of their performance. In this paper we define an index for evaluating the fishers- performance, as well as the determinants of such performance in terms of individual attributes (e.g., fisher age and experience, and physical features of fishing vessels), choice variables (amount of fishing time, species targeted) and the fishing season (windy, rainy, dry).

The use of a performance index here was mainly for comparison purposes. It is not our intention to suggest specific categories to define a 'good' or 'bad fisher'. Hence, determination of fishers' performance and the variables related with catch rates and relative fishing efficiency could help to identify changes in exploitation patterns of fishers related to changes in fishers' operations and variations in the stock under exploitation. For instance, an index such as the fishing performance could show trends of marginal catch rates of individual fishers in each community. In this way, when the performance of all fishers is affected despite the characteristics of their boats or other variables, this would indicate that the fishery as a whole is in trouble. That is, a general increase in fishing efficiency could lead to a decrease in the individual yield once the optimal level of production of the exploited resources has been attained, regardless of how efficient a fisher is and independently of the fishing power (stock externality, see Seijo *et al*. 1998).

Now, if some fishers catch more than others do, what determines these differences?, especially if the they fish in the same areas and operate under the same constrains (regulation, environmental conditions). Sampson (1992) states that catch and profits in a fishery depend on abundance and distribution of the stock under exploitation, human and capital resources, and applied technology. He states that technology tends to evolve rapidly, having an impact on the flows of fishing profits, stability, and dynamic behavior of the whole system. However, he does not elaborate on what he defines as the human component in this process. Allen and McGlade (1986) assert that fishing contains two elements: 'discovery' and 'exploitation'. Thus, knowledge of the resource distribution and availability, combined with 'working hard', can result in high catches. On the other hand, Forman (1967) states in the same direction, that fishing success can be associated with familiarity with fishing spots (discovery) and , youth, good health, sobriety, willingness to take risks, and ability to command a crew (exploitation), as shown in the case of a small-scale Brazilian fishery he analyzed.

In the present study, the analysis permitted a partial testing of the hypotheses initially stated. It was hypothesized that higher catches and profits would result from the use of large boats with high power, fishers with high fishing experience, and preference for the most profitable species as a target in their trips. Although boat attributes were significant in San Felipe and Dzilam Bravo, results show the influence of the number of trips on catch rates in all communities was consistently a determinant factor in the how much they catch and how much they earn (considering the species targeted and their price). Even for fishers in the 'below average' category the frequency fishing (number of trips undertaken) are important in the definition of the catch variability. Yet, some variability still remains unexplained in the three communities. Other elements need further analysis, such as the unmeasured effect of errors in the independent and dependent variables, or other factors associated to the 'human component '.

The 'skipper effect' has been widely discussed (Pálsson and Durrenberg 1982, Gatewood 1984). Rutan and Tyedmers (2007) state that the problem is that people define this concept differently. Some include effort as a dimension of the skipper effect and some do not. Thus, analyses that explore this effect may not be discussing the same phenomenon. In this study, we associated fishing trips with the human component, as the definition of number of trips undertaken would involve a decision depending on the constraints and goals of the fishers. However, to split out the potential overlapping effects of the fishers and the vessels, it is necessary to assess the performance of the same skipper moving between vessels (see Hilborn and Ledbetter 1985, Rutan and Tyedmers 2007). Other factors associated with a given fishing trip could be linked to the fishing gear and not exclusively to the boat, especially in small-scale fisheries. For example, Arceo and Seijo (1989) found that in the use of 'hookah' to fish lobster, time was the only significant variable associated with catches (with variability still remaining unexplained), compared to that of 'stationary fishing gears' such as traps, nets, and artificial habitats, for which depth, despite the time the gear was immersed in the water, were significant variables.

The selection of target species as a choice variable was significant only in Dzilam Bravo. According to the results we could state that some fishers, especially in this fishing community may aim to maximize profits through different strategies besides taking advantage of the characteristics of their boats. The benefits derived from a trip con be derived as stated before by:

i) High volumes of a species of low value,
ii) Small amount of profitable species, or
iii) A combination of both.

The later seems more common among small-scale fishers in the region. However, some fishers may be happy by reaching benefits that compensate their travel costs (Salas *et al.* 2004).

Results derived from the present analysis can help to provide insights into the understanding of small-scale fisher operations within a fishing season in the study area and can help to highlight what factors affect fisher decision, and how this could affect the resource conservation. Understanding how fishers operate and what factors can impact catches and furthermore the resources can guide managers to define more viable management strategies that allow reaching the goals for policy management.

ACKNOWLEDGMENTS

We thank fishers from the cooperatives “Pescadores Unidos de San Felipe”, “Dzilam Bravo” and “Coxcaiba” for the data provided which made possible the present study. We also thank the technical support from Guadalupe Mexicano and Tiburcio Castro for data collection. We appreciate the comments from Juan Hernandez and Daniel Gaertner on an earlier draft of this paper. The first author thanks CONACYT (Mexico) and ICCS, (Canada) for financial support. The second author acknowledges support from the Natural Sciences and Engineering Research Council of Canada, the Social Sciences and Humanities Research Council of Canada, and the Pew Fellows Program in Marine Conservation.

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