Catch Per Trip Variability Analysis Related to Several Fishing Effort Components in the Small-scale, Large Pelagic Fishery in Martinique (FWI): An Attempt to Define More Accurate Fishing Effort Units Function of the Different Types of Fish "Aggregators"

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ABSTRACT

As in most of the islands of the Lesser Antilles, the small-scale large pelagic fishery in Martinique (FWI) is based on the exploitation of fishes concentrated around three types of "aggregators": flotsams, seamounts and Fish Aggregating Devices (FADs). The technical and human means implemented by the small scale fishermen to catch the fishes are the same whatever aggregator they target.

Due to the lack of consistent data series, CPUEs are commonly expressed as "catches by trip". The influence of several other fishing effort components on the catches per trip data issued from the small scale large pelagic fishery in Martinique was modelled using General Linear Models. The aim of the analysis is not to get a predictive model but to identify the variables explaining most of the catch per trip variability so as to evaluate the fishing effort more accurately.

At the scale of the global large pelagic fishery, the most influent variables were the type of aggregator exploited during the trip ("type of fishing") and the depth layer prospected with the fishing gears. The same analysis was conducted within the strata defined by the types of fishing. Most of the catch per trip variability of the moored FAD fishery was explained by the use or not of drifting longlines allowing to catch large adult pelagics (essentially Thunnus albacares and Makaira nigricans. The fishing effort components available seemed to be inefficient to explain the catch per trip variability of the very random offshore trolling fishery. The catch per trip variability of the coastal trolling fishery depended mainly on the trip length.

Generalized Linear Models appeared to be efficient to process the data issued from the small skewed data sets often encountered in the insular context. The results suggest several fisheries should be defined within the large pelagic fishery so as to better assess the catch per trip variability but also the age structure of the catches. The fisheries should be classically defined by the fishing area, the species targeted, the fishing gears but also by the type of aggregator prospected. The moored FAD fishing seems to substitute effective fishing time (local fishing efficiency) to costly travelling time (local searching efficiency) compared to the traditional coastal trolling fishery.

KEY WORDS: FAD, Martinique, GLM

INTRODUCTION

In Martinique as in most of the Lesser Antilles islands, pelagic resources are traditionally exploited by small scale fishermen aboard 6 to 7 m undecked boats. Fishermen stay at sea in the daytime and use mainly trolling lines. The main traditional fishery is the offshore trolling under drifting flotsams which occurs from January to June, when flotsams are numerous enough on the Atlantic Coast of the island. The main specie targeted is *Coryphaena hippurus* but *Acanthocybium solandri* and juveniles tunas (Thunnini) are also commonly caught. Fishermen also troll over seamounts near the shore for *Thunnus atlanticus*, *Sphyraena barracuda* and *Scomberomorus* sp. all year long in some harbors.

Moored FADs were first introduced in early 1980s to retarget the intense fishing effort deployed on the coastal resources toward large pelagic stocks. The moored FAD fishery has been developing since mid-1990s in Martinique, both on the Caribbean and Atlantic coasts and currently produces around 2000 metric ton per year. The main species targeted are *Makaira nigricans*, *Thunnus albacares* and *Thunnus atlanticus.*

Assessing the real impact of this new fishery is difficult because of the lack of an exhaustive data collection system. The fishermen sell directly their catches to the consumers in the 150 landing sites recorded around Martinique and monitoring the fisheries is very uneasy. However, IFREMER has gathered very detailed information on catches and fishing effort of a little sample of trips targeting large pelagics.

Assessing the evolution of the exploitation of large pelagic fishes and evaluating the impact of the development of the moored FAD fishery is also difficult because of the necessity of both evaluating the exploitable living resources and the impact of fishing on these resources: that is drawing relations between catches, fishing effort, and abundance. A useful theoretical frame on fishing effort and power is provided by Gascuel (Gascuel et al. 1995).

Traditionally, the yield at a given time t (Y(t)) is related to the average available biomass at t (Bm(t)) and to the fishing mortality (F) following:

$$Y(t)=Bm(t)*F(t)$$

The fishing mortality F is related to the fishing effort (f) and the catchability at t (q(t)) following :

$$F(t)=q(t)*f$$

Catchability can be divided into two components: one related to the availability and vulnerability of the fishes ("availability" = d) and the other to the fishermen ability to find and catch the fishes ("global fishing power" = Pg). In this case we assume that the fishing effort is "nominal" (fn) i.e. represents the fishing effort directly measurable by fishery managers.

The yield at t is:

$$Y(t)=Bm(t)*d(t)*Pg(t)*fn$$

However, if we assume that the fishing effort represents the real fishing pressure applied to the stock by fishermen, the fishing effort is "effective" (fe). Y becomes:

$$Y(t)=Bm(t)*d(t)*fe$$

All the parameters describing the fishing trip shall be considered as effective fishing effort parameters.

Nevertheless, these theoretical formulas cannot be used to asses the large pelagic fishery in Martinique because the available data are very limited (no abundance data and no long series of catch and effort to evaluate the fishing power).

However, Generalised Linear Models (GLM) can be used to establish a linear relation between our basic "CPUE" (the catches per trip (Y(trip)) and the explanatory variables available (Xi), namely the fishing effort parameters:

$$g(avg(Y(trip)))=a_1X_1+a_2X_2+....+a_nX_n$$

OR

$$g(avg(CPUE))=a_1X_1+a_2X_2+....+a_nX_n$$

avg is the average and the g is the link function used in the Generalised Linear Model.

The aim of the study is not to get a predictive model of the catches per trip function of the values of Xi but to assess and compare statistically the influence on the variability of the catches of each of the fishing effort parameter that have been collected. Hence we will try to isolate the more accurate information to collect for monitoring accurately the fisheries.

The second major advantage of generalized linear models is to handle non normally distributed data. This property is very important in the case of CPUEs which generally follows non normal distribution and, in our case, cannot be easily normalized.

MATERIAL AND METHODS

Data

The data have been collected by Ifremer during landing road surveys in three landing areas in Martinique: one on the Southern Atlantic Coast (Le François), one on the Northern Caribbean Coast (Le Prêcheur, St-Pierre and Le Carbet) since May, 1998 and one on the Southern Coast (Ste-Luce) since March, 2000. The two investigators have been surveying the three areas every week. The sampling plan is not a simple random one so data recorded cannot be extrapolated to the whole fishery.

The investigators identified all the fishes landed and measured the fork length (FL) and the weight at each site for half a day, until all the boats at sea were returned. They also recorded detailed information on the fishing trip gathered in Table 1. The boats surveyed were not identified and fishermen willingly answered the questions. The data processed are issued from 1026 fishing trips surveyed from May, 1998 to May, 2001 (301 in 98/99, 259 in 99/00 and 424 in 00/01).

Table 1. Fishing trip parameters gathered during Ifremer road surveys

Date
Sampling site
Time of departure
Time of arrival
Type of boat
Number of engines
Engine power
Crew size
Gas consumption
Fishing area: Island coast (N/S/E/W)
Trolling during the whole trip (Y/N)
Type of fishing (type of aggregator)
Fishing area(s): name of FAD or seamount
Time of arrival and departure in each fishing area
Type and number of fishing gears used in each fishing area
Type of offshore trolling aggregation (flight and/or flotsam)
Type of flotsam if any
Time of fishing on each offshore trolling aggregation
Type and number of fishing gears used on each aggregation

Model Development

The dependent variable studied is the total catches aggregated by fishing trip (Y). The total catch per trip can be assimilated to a Catch per Unit of Effort (CPUE). The Y variable distribution seems to be log linear or Gamma distributed (Figure 1). Attempts to normalize Y into log(Y+b) (with b a positive parameter) failed because of the presence of fishing trips with zero catch that skewed the transformed Y distribution. Hence classical linear models and analysis of variance could not be used to assess the effect of the fishing trip parameters on Y that is why Generalized Linear Models were used. Moreover, the surveys depending on the availability of the investigators (holidays…) and the sampling plan having slightly evolved over the years, the sample is not rigorously balanced and the use of GLM allow to rebalance it through the marginal means calculation (Gascuel 1994).

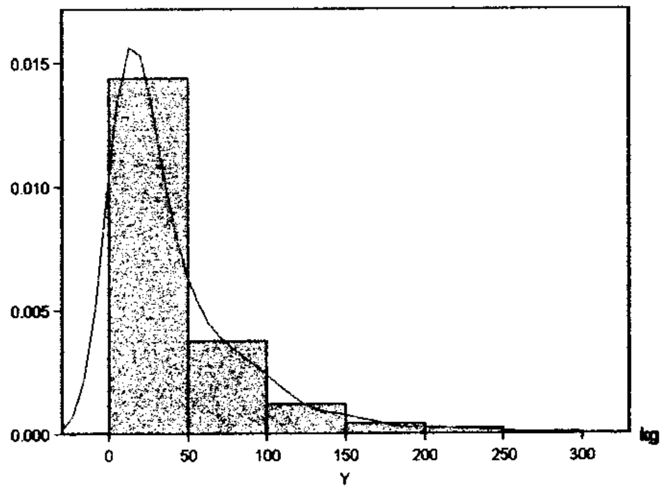

Figure 1. Total catch per trip frequency distribution

Generalized Linear Models (GLMs) extend linear models to accommodate both non-normal response distribution and transformation to linearity (Venables and Ripley 1999). According to Venables and Ripley (1999), the comprehensive reference on GLM is Mc Cullagh and Nelder (1989) and a generalized linear model can be described by the following assumptions:

i) a random dependent variable y observed independently at fixed values of explicative variables $x_1, x_2, \ldots, x_p$
ii) the explicative variables may only influence the distribution of y through a single linear function called the linear predictor $\eta = a_1x_1+a_2x_2+\ldots+a_px_p$
iii) the distribution of y belongs to the exponential family (see Lindsey, 1997, p.10)
iv) The mean μ of y is a smooth invertible function of the linear predictor: $\eta = m(\mu)$, $\mu = m^{-1}(\eta)$, with m is the "link function"

Here, from the shape of the distribution of the dependent variable Y we assume it belongs to the Gamma family which belongs itself to the exponential family. In fact, in fishing science, the Gamma distribution is commonly used to describe CPUEs (Mahevas, 2000). The explicative variables (X_i) selected to model Y variability are listed in Table 2.

The inverse, identity and log functions were tested as link function and the best fits were obtained with $m(\mu) = \log(\mu)$. Actually the linear predictor may be written:

$$\eta = \log(\mu) = a_1X_1+a_2X_2+\ldots+a_pX_p$$

Table 2. Fishing trip parameters selected as explicative variables in GLM modelling

Name	Decription	Type	Category
eq	Crew size	Continuous	Fishing effort
tsnum	Trip length (h)	Continuous	Fishing effort
nbBl	Number of vertical longlines used	Continuous	Fishing effort
conso	Gas consumption	Continuous	Fishing effort
cP	Engine power class (1 to 4)	Factor	Fishing effort
Bl	Use of longline (T/F)	Factor	Fishing effort
nbT	Number of trolling lines used	Continuous	Fishing effort
codehf	Name of the seamount fished	Factor	Fishing effort
fm	Fishing area: Island coast (N/S/E/W)	Factor	Geographic (Fishing area)
zone	Site location	Factor	Geographic (Landing point)
site	Sampling site	Factor	Geographic (Landing point)
anech	Year	Factor	Time
Ysaison	High production season (T/F)	Factor	Time period
saison	Offshore trolling season (T/F)	Factor	Time period
mois	Month	Factor	Time period

Variable Selection

The parameters issued from Table 1 were sorted and some categorised (cP, zone) to get the explicative variables (Table 2). The effective fishing time on each fishing area was not selected because this information has only been recorded since the end of 2000. The names of the FADs were also not selected because one FAD can be called with different names and their precise location is very bad known. Data on gears were summarized into the BI variable: use or not of single vertical longline during the trip.

Model Selection

All the calculations were performed with S PLUS 2000 for Windows using the glm related functions.

> "Statistical models contain both elements (...) *systematic effects* and *random effects*. The value of a model is that often it suggests a simple summary of the data in terms of the major systematic effects together with a summary of the nature and magnitude of the unexplained or random variation." (Mc Cullagh and Nelder 1989).

Hence, the building model consists of selecting the combination of explicative variables which better fit the observations with less estimated parameters as possible (systematic effect) and then to check if the residuals produced by the model are randomly distributed (random effect). The variables can be considered either alone (main effects) or combinated (interaction effects).

The candidate model must reach a trade-off between underfitting the data that is narrowing the null model (no parameter, largest variance) and overfitting the data that is tending to the saturated model (as many parameters as observations, null variance). So for one model, once must assess the variability (called deviance in this case) explained by the model but also the number of degree of freedom of the model, that is the number of parameter that must be estimated for using it.

Following Gaertner et al.(1999), we did not use the stepwise selection procedure to build our models but the Akaikes's Information Criterion (AIC) which allows to compare different models based on the same set of observations and to emphasize the parsimony (reducing the number of estimated parameters): AIC=-2(log-likelihood)+2K=D+2K with K is the number of parameters in the model and D the deviance. The model with the smallest AIC is defined as the parsimonious model (Gaertner et al. 1999).

Mahevas (2000) provided a comprehensive method to study the structure of the residuals:

The structure of the residuals was assessed using the standardised residuals of deviance(rDi):

$$_{Rdi}=sign(y_i-est(y_i)\ddot{O}(2y_i log(y_i/est(y_i))+2(n_i-y_i)log((n_i-y_i)/n_i-est(y_i)))$$

where $est(y_i)$ is the estimated value of y_i

$$rD_i=Rd_i/\ddot{O}(1-h_i)$$

where h_i (leverage)is the ith element of the diagonal of the H matrix

If the model is correct, the standardised residuals of deviance are asymptotically distributed following a centered reduced normal distribution function. The squared residuals of deviance were also used to detect the observations which had the biggest influence on the fit of the model.

Actually the Cook's distance was used to detect the observations which had the biggest influence on the estimation of the parameters of the model: Cook's distance $= R^2_{Pi}.hi/k(1-hi)^2$ where R^2_{Pi}.are the partial residuals.

The most influent observations were systematically studied, being sometimes doubtful and then deleted. Nevertheless, they were also systematically deleted and the model readjusted on the new data set to assess if the residual deviance decreased.

Modelling Strategy

In the case of our analysis, the explicative variables can be grouped into 5 categories: fishing effort (FE), geographic (fishing area) (FA), geographic (landing point) (LP), time (T), time period (TP).

FE = tsnum+cP+eq+tp+BI+conso

FA = fm

LP = site OR zone
T = anech
TP = mois OR saison OR Ysaison

The first step consisted in selecting a subset of variables among the list of the explicative ones. Each candidate variable was modelled alone as the only explicative variable and the hypothesis that the GLM slope coefficient was zero was tested with the use of the Wald test.

The basic multivariate model tested according to the AIC criterion ("AIC" function in S PLUS 2000) was: Y~FE+FA+LP+T+TP
For LP and TP, the different modalities were tested successively and the model with the smallest AIC selected.

Then all the interaction effects between all the variables in the best model were tested with the "step" function which selects the model with the smallest AIC. The "step" function was repeated until no new term is selected in the model. Only interactions "which make biologic sense "were retained (Hosmer and Lemeshow, 1989 in Gaertner et al. 1999).

The variance of Y was modelled for the whole large pelagic fishery in Martinique and the more significant and explicative variable was used to stratify the sample. Then similar modelling was performed within each strata.
Some particular explanative variables were add to the basic model to try to better fit observations in the case of the FAD fishery (nbBI) and of the coastal fishery (nbT, codehf). The model selection was performed in the same way.

Explanative Variable Effects Assessment

The aim of the study is to analyse the compared effects of the explanative variables on the variability of the catches per trip. When the best model is defined, the influence of the variables on the variability of Y can be assessed with different tools:

i) The Wald's test for nullity of the a_i coefficient of each single degree of freedom variable: if the estimated coefficient of the variable is significantly not null, the variable influences the model. A variable is usually considered as significant for $t \geq 1.96$.

ii) The deviance explained by the variable: terms are added successively in the model and the new deviance explained by the new term is calculated in relation to the terms previously added. The intrinsic deviance explained by a variable without relation with the other variables is obtained while adjusting the model with the considered term in the last position. This is the way chosen to compare the deviance explained by each term. The intrinsic deviance explained by degree of freedom of the variable was also used to compare the parsimony of the terms. A Fisher's test is used to test the significativity of the explained deviance of each term.

RESULTS

Variable Selection

All the candidate variables were significant ($p < 0.05$) and the use or not of longline (BI), the type of fishing (tp), the engine power (cP), the trip length (tsnum), the gas consumption (conso), the high yield season (Ysaison) and the offshore trolling season were highly significant ($p < 0.001$).

Variables Explaining the Variability of the Catches Per Trip of the Whole Large Pelagic Fishery

Data issued from 1026 fishing trips were processed and the smallest AIC statistic was reached for:

$$\log(\mu) = \mathbf{BI + tp + tsnum + conso + eq + site + saison + anech + fm + BI{:}tsnum + conso{:}anech}$$

This model explains a large part (33%) of the total deviance of Y for 48 parameters estimated. The standardised residuals of deviance are roughly normally distributed (Figure 2). We can notice that the fit is less accurate for short FAD fishing trips with big catches. Five observations with big Cook's distances were deleted to improve the fit. Squared residuals of deviance and Cook's distances show no particularly influent observation. (Figure 3). The values plotted on figure 3 are the yields per trip showing the most influent observations are those corresponding to the higher catches.

The variables explaining the biggest part of total deviance and the highest explained deviance per degree of freedom are the type of fishing (tp) and the use of or not of single vertical longline (BI) (Table 3). tp explains the biggest part of the overall deviance whereas BI explains the highest deviance per degree of freedom. Both of the variables are significant regarding Wald's test and the explained deviance. The crew size (eq) and the season for offshore trolling (saison) are also significant for both tests and explains a smaller part of Y variability. The site and the year effects explain substantial total deviance but are not significant regarding to Wald's test.

The "type of fishing" effect explains the biggest overall catch per trip variability for three degrees of freedom. Moreover, the "BI" effect explains the other big part of catch variability and is closely related to the "tp" effect because the single drifting longline is only used in one type of fishing: the moored FAD fishing.. Hence the "tp" effect was chosen to stratify the sample. Similar modelling was conducted successively for the FAD fishing trips, offshore trolling and coastal trolling trips to assess the more explicative factors of the catches within each fishery.

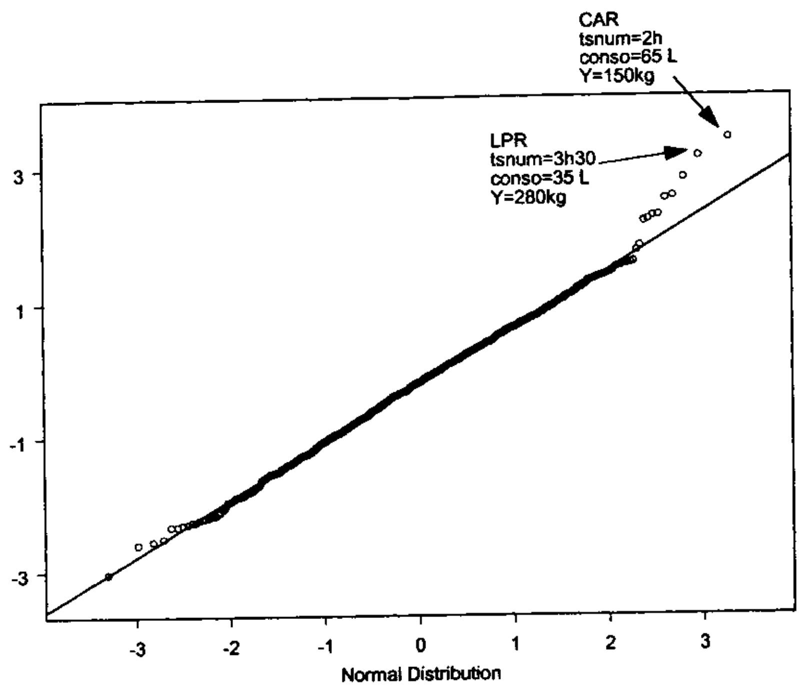

Figure 2. Half normal plot of the standardized residuals of deviance

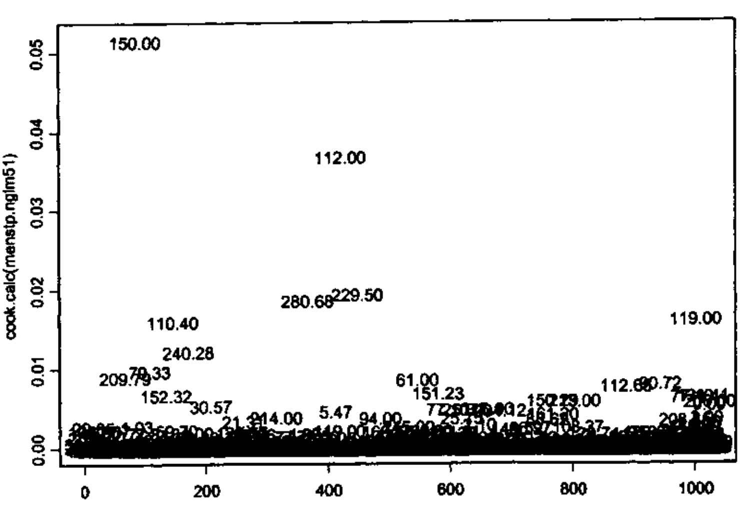

Figure 3. Cook's distance against observations

Table 3. Factors explaining the deviance of the catch per trip in the whole large pelagic fishery in Martinique

	Df	Deviance	Dev/Df	Res.Df	Resid. Dev	F Value	Pr(F)
Bl	1	37.3292	37.3	1003	855.231	46.80022	0.00000000
tp	3	40.39884	13.4	1003	855.231	16.88291	0.00000000
eq	1	9.72325	9.7	1003	855.231	12.1902	0.00050186
saison	1	8.10957	8.1	1003	855.231	10.16711	0.00147506
tsnum:eq	1	5.8531	5.9	991	822.105	7.33819	0.00686830
site	7	37.65182	5.4	1003	855.231	6.7435	0.00000008
Bl:tsnum	1	4.9094	4.9	982	799.584	6.15495	0.01327154
conso:anech	3	6.4957	2.1	979	793.088	2.71461	0.04370791
Bl:fm	4	7.8324	1.9	983	804.493	2.45492	0.04428787
conso	*1*	*3.38778*	*3.4*	*1003*	*855.231*	*4.2473*	*0.03957608*
site:anech	*11*	*27.2730*	*2.5*	*992*	*827.958*	*3.10842*	*0.00039542*
tsnum:fm	*4*	*9.7790*	*2.4*	*987*	*812.326*	*3.06501*	*0.01594935*
anech	*3*	*6.54533*	*2.2*	*1003*	*855.231*	*2.7353*	*0.04251162*
tsnum	*1*	*1.5545*	*1.5*	*1003*	*855.231*	*1.9489*	*0.1630220*
fm	*4*	*7.4332*	*1.9*	*1003*	*855.231*	*2.32980*	*0.05436714*

Non significant effects italicised

Variables Explaining the Variability of the Catches Per Trip in the Moored FAD Fishery

The crew size (eq) and the offshore trolling season (saison) variables were not significant regarding the univariate Wald's test. They have not been retained for the multivariate model selection process.

The smallest AIC statistic was reached for:

$$\log(\mu) = \mathbf{BI + conso + site + Ysaison + anech + site{:}anech}$$

This model explains a large part (29%) of the total deviance of Y for 26 parameters estimated. The data issued from 490 fishing trips were processed.

The standardized residuals of deviance are roughly normally distributed. Two observations with big Cook's distances were deleted to improve the fit. Squared residuals of deviance and Cook's distances show no particularly influent observation. The most influent observations are also those with the bigger catches.

The variable explaining the biggest part of total deviance and the highest explained deviance per degree of freedom is the use of, or not of, single vertical longline (BI) (Table 4). BI is highly significant for both tests. The FAD high yields/low yields season is also significant for both tests and explains a substantial part of deviance for only one degree of freedom. The other effects are not significant regarding the Wald's test and explain less deviance. The most explanative and significant variable is so the use or not of single vertical longline

Table 4. Factors explaining the deviance of the catch per trip in the moored FAD fishery in Martinique

	Df	Deviance	Dev/Df	Res.Df	Resid.Dev	F Value	Pr(F)
BI	1	21.48771	21.5	476	494.3337	21.95134	0.000003673
Ysaison	1	8.88716	8.8	476	494.3337	9.07891	0.002726253
conso	*1*	*4.94093*	*4.9*	*476*	*494.3337*	*5.04753*	*0.02512745*
site	*9*	*25.02345*	*2.7*	*476*	*494.3337*	*2.84037*	*0.002890876*
site:anech	*9*	*24.40199*	*2.7*	*467*	*469.9317*	*2.76983*	*0.003621247*
anech	*3*	*4.85513*	*1.6*	*476*	*494.3337*	*1.65330*	*0.1763182*

Non significant effects italicised

Variables Explaining the Variability of the Catches Per Trip in the Offshore Trolling Fishery

The crew size (eq) and the high yields season (Ysaison), the island coast (fm) and the trip length (tsnum) variables were not significant regarding the univariate Wald's test (Table 5). They have not been retained for the multivariate model selection process.

The offshore trolling essentially occurs from January to June and only the 183 trips recorded during this period have been taken into account in the model.
The smallest AIC statistic was reached for:

$$\log(\mu) = zone + anech$$

This very simple model only explains (13%) of the total deviance of Y for eight parameters estimated. The standardised residuals of deviance are roughly normally distributed.. Squared residuals of deviance and Cook's distances show no particularly influent observation. The area where the landing point is located (zone) and the year (anech) are significant for both tests but explain very few deviance. No fishing effort related variables have been retained in this model.

Table 5. Factors explaining the deviance of the catch per trip in the offshore trolling fishery in Martinique

	Df	Deviance	Dev/Df	Res.Df	Resid.Dev	F Value	Pr(F)
zone	3	12,97765	4,3	177	124,492	8,04851	0,00004669
anech	3	8,660421	2,9	177	124,492	5,371042	0,00145979

Non significant effects italicised

Variables Explaining the Variability of the Catches Per Trip in the Coastal Trolling Fishery

The crew size (eq) and the high yields season (Ysaison), the offshore trolling season (saison) and the number of trolling lines used (nbT) variables were not significant regarding the univariate Wald's test (Table 6). They have not been retained for the multivariate model selection process. The smallest AIC statistic was reached for:

$$\log(\mu) = tsnum + fm + tsnum{:}fm$$

This model explains 22% of the total deviance of Y for 10 parameters estimated.. The data issued from 254 fishing trips were processed. The standardised residuals of deviance are roughly normally distributed. One observation with big Cook's distances were deleted to improve the fit. The trip length (tsnum) and the island coast (fm) are significant for both tests and explain most of the global deviance and of the deviance per degree of freedom.
Another model was tested including the precise fishing area (seamounts). The new effect was not retained through the model selecting process.

Table 6. Factors explaining the deviance of the catch per trip in the coastal trolling fishery in Martinique

	Df	Deviance	Dev/Df	Res.Df	Resid.Dev	F Value	Pr(F)
tsnum	1	5.47595	5,5	249	120.3008	11.65535	0.00074856
fm	3	9.05218	3	249	120.3008	6.42241	0.00033272
fm:tsnum	*3*	*3.51250*	*1*	*246*	*116.7883*	*2.49208*	*0.06072916*

Non significant effects italicised

DISCUSSION

Representativity of Data

As mentioned above, the data sample used for this study is not representative of the whole fishery in Martinique. The only other available catch per trip data are issued from logbooks collected both in Martinique and Guadeloupe but without simple random sampling plan. This dataset is also not representative of the whole fishery. However, this data set is bigger which allows a wider coverage of the fishery (11,678 fishing trips recorded over five years). The yearly coefficient of variation of Y in the sample used for this study ranges from 1.06 to 1.14 for the moored FAD fishery. It is comparable to the same coefficient for the same fishery in Guadeloupe between 1992 and 1995 (0.97 to 1.41). The yearly coefficient of variation of Y in the sample ranges from 0.62 to 0.87 for the offshore trolling fishery. It is comparable to the same coefficient for the same fishery in Martinique between 1994 and 1995 (0.76 to 0.83). So we can suppose that the size of the data sample used in this study is not too small to be compared to bigger samples with wider coverage of the fishery.

Variables Explaining the Variability of the Catches Per Trip of the Whole Large Pelagic Fishery

The type of fishing (tp) and the use of longline (BI) explain most of the deviance in the model. It implies that, in this sample issued from Martinique, different fisheries must be distinguished within the large pelagic fishery regarding to the catch per trip variability patterns. A fishery is commonly defined by:

i) A fishing area,
ii) One or several target species,

iii) A fishing gear,
iv) A "fishing practice".

In this case, the "fishing practice" corresponds to the type(s) of fish "aggregator(s)" that is (are) exploited by the fishermen during the trip. In fact, the absence in the Lesser Antilles of big hydrological fronts related to areas of high trophic interest for large pelagics does not allow the fishes to gather into large schools. The only way for the small scale fishermen to exploit these pelagic resources is to take advantage of local concentrations around different types of "aggregators" to catch fishes that would either be "virtually nonexistent" (Sharp, 1978 in Bertrand 1999) due to their very low global density. In Martinique, the aggregators exploited by the fishermen are the drifting flotsams, the seamounts and more recently, the Fish Aggregating Devices (FADs).

The large part of variability of Y explained by the "BI" effect highlights the fact that the concentrations of fishes found around the aggregators are only partially exploited by the small scale fishermen which only prospect the sub-surface layer. The use of the vertical drifting longline deeply influence the catch per trip variability patterns in our sample. This technique was introduced in 1994 in Martinique and allowed to increase the average production per trip by catching big adults pelagic under the moored FADs (Figure 4). This statement was confirmed by testing the GLM model: $Y \sim Ysp_1 + Ysp_2 + \ldots + Ysp_n$ where Yspi are the catches per trip per species i. The biggest part of the deviance of Y was explained by the catches of big pelagics (YGP), namely adult *Thunnus albacares* and *Makaira nigricans* and YGP was positively correlated with Y. Moreover, the small scale fishermen only use vertical longline up to depth of 150 - 200 m because of the absence of winch in their boats but experimental fishing showed the deeper presence of *Xiphias gladius*, *Thunnus obesus* and *Thunnus allalunga* under the moored FADs (Taquet et al. 1998).

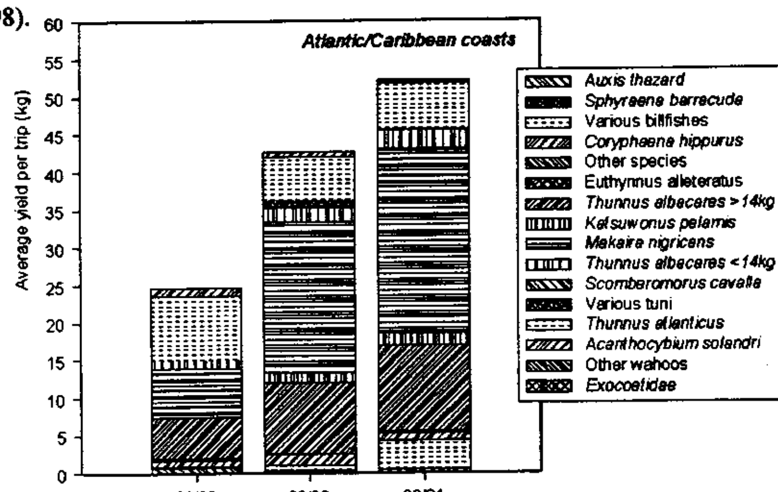

Figure 4. Average catches per FAD fishing trip per species, Martinique

According to the results based on the sample used in this study, the strategic choice of the aggregator (tp) and of the depth layer to prospect (BI) appear to be the fishing power components that explain most of the variability in the catches of the large pelagic fisheries in Martinique. The combination of those two components allows to define the fisheries exploiting the large pelagic fishes in Martinique (Table 7). The use of accurate definitions of fisheries is important to better assess the level of exploitation of the stocks because one fishery correspond to one "exploitation diagram" that is a size frequency distribution within the catches. Hence the age structure of the fishes caught is linked directly to the fishery in which operate the fisherman. For example in our fishing trips sample, the moored FAD trolling mainly target juvenile *Thunnus atlanticus* (Figure 5a) whereas the moored FAD longlining fishery essentially target adult fishes such as *Makaira nigricans* (Figure 5b). Actually, information on the type of aggregator and on the depth layer prospected (fishing gears) appear to be important to be collected to monitor the small scale large pelagic fishery in Martinique.

Table 7. Definition of the large pelagic fisheries in Martinique

Fishery	Fishing area	Target species	Fishing gear	Fish aggregator
Moored FAD longlining	Around the island	*Makaira nigricans* *Thunnus albacares*	Vertical longline	FAD
Moored FAD trolling	Around the island	*Thunnus atlanticus*	Sub-surface trolling lines	FAD
Offshore trolling	Mainly on the Atlantic coast	*Coryphaena hippurus* *Acanthocybium solandri* *Thunnini*	Sub-surface trolling lines	flotsams
Coastal trolling	Mainly on the Atlantic coast	*Thunnus atlanticus* *Scomberomorus sp* *Sphyraena baraccuda*	Sub-surface trolling lines	seamounts

According to the definition of the catchability components given by Gascuel et al. (1995) (Figure 6), the one-off choice of the aggregator is a global fishing efficiency (capacity to find the available fishes) component whereas the choice of the depth layer is a local fishing efficiency. Hence in our fishing trip sample, the variability of the catches seems to depend both on a strategic component at a global level: the choice of the aggregator and therefore on a fishing strategy component at a local level: the use or not of longline.

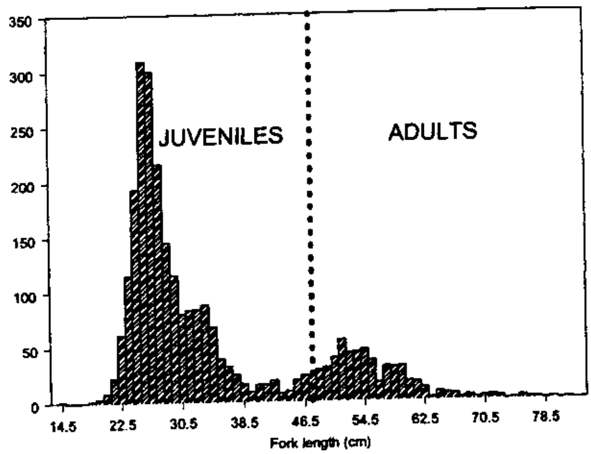

Figure 5a. Size frequency distribution of the *Thunnus atlanticus* caught by the moored FAD trolling fishery. Martinique, 1998 -2001

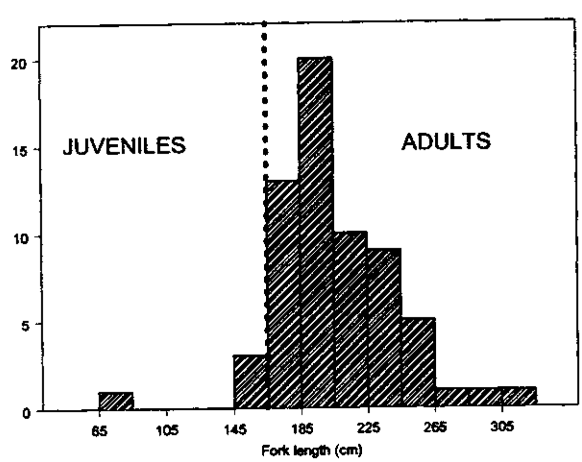

Figure 5b. Size frequency distribution of the *Makaira nigricans* caught by the moored FAD longlining fishery. Martinique, 1998 -2001

Variables Explaining the Variability of the Catches Per Trip in the Moored FAD Fishery

The variable explaining most of the catch per trip variability in the moored FAD fishery in Martinique is the use or not of vertical drifting longline (BI). It is worth to note this variable explicit the difference between the two moored FAD fisheries defined above, difference relying on the fishing gear used. Hence the theorical definitions of the two moored FAD fisheries seem to be correspond to two strata in the catches per trip.

In Gascuel et al.'s (1995) typology (Figure 6), "BI" is a fishing power component, namely of the local catching efficiency (el). The other explanative variable is a seasonal parameter which can be related to the availability "d" of the fishes function of the time period. So if the fishing mortality F is d*Pg*fn, in an attempt to precise the pressure of the FAD fishery on the stocks, one can express F as : $F_{FAD} = d * el * \varepsilon$.

The variables: use or not of longline (BI) and fishing season (Ysaison) appear to be particularly important to collect to monitor the moored FAD fishery.

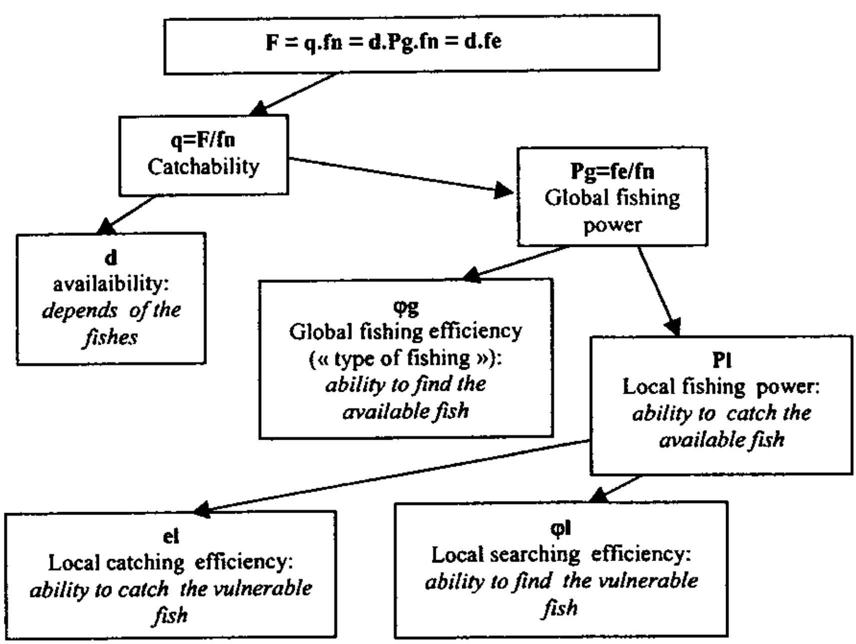

Figure 6. Components of the catchability (redrawn from Gascuel et al. 1995)

Variables Explaining the Variability of the Catches Per Trip in the Offshore Trolling Fishery

The explanative variables are the area where the landing point is located (zone) and the year (anech). The main fishing grounds for offshore trolling are on the Eastern Coast of the island, so the location of the harbour (zone) is very important to access the fishing areas. The offshore trolling is a very random fishery whose catches rely on the ability of the fisherman to find schools of dolphin fishes based on very few information (currents, bird flights...). The fishing effort parameters collected for this study seem to be inefficient to quantify this subjective efficiency because all the fishing trips appear to be identical with our parameters (long, involving high powered boats with the same fishing gears and a high gas consumption). So only geographical and yearly variations are retained in the model which is not of high interest to monitor the fishery.

Moreover, only the successful offshore trolling trips are recorded in our sample because if they catch nothing, the fishermen don't go to the market where the surveys are implemented.

Variables Explaining the Variability of the Catches Per Trip in the Coastal Trolling Fishery

The main explicative variable is the trip length which can be considered as a nominal fishing effort unit, providing also some information on the local searching efficiency (φl): a long fishing trip usually means either the fisherman chose to spend a long time travelling to a seamount located far away from the coast either he struggled to find the fish over the seamount and spent a long time searching. Contrary to the moored FAD fishery, the local catching efficiency does not seem to explain the variability in the catches. In an attempt to precise the pressure of the coastal fishery on the stocks, one can express F as: $F_{COAST} = d * \varphi l * E(tsnum) * \varepsilon$. Hence, the trip length appear to be the more important information to collect to monitor the coastal trolling fishery.

CONCLUSION

To conclude, the use of Generalized Linear Models appear to be an efficient method to process the data issued from small skewed data sets which are very often the only available data in the small insular countries where the cost of the data collection is very high compared to the amount of data collected.

According to the results based on the sample used in this study, the monitoring of the large pelagic fishery in Martinique and obviously in most of the Lesser Antilles countries, should include the new definitions of pelagic fisheries presented in Table 7 to better assess the variability and the age structure of the catches function of the strategic choice of the aggregator and of the depth layer prospected.

The fishing effort of the offshore trolling fishery appears to be very uneasy to evaluate because this is a very random fishery. The moored FAD fishing seems to substitute effective fishing time (local fishing efficiency) to costly travelling time (local searching efficiency) compared to the coastal trolling.

The next step in the analysis of the fishing effort components of the large pelagic fishery in Martinique will be to try combining the three models obtained for the three types of fishing (moored FAD fishing, offshore trolling, coastal trolling) into a General Additive Model (GAM) so as to better explain the variability of the catches per trip at the scale of the whole fishery.

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