The Gulf of Mexico Grouper Fisheries: Heterogeneous Fleet and Expectations in Fishermen's Decision

Hamady Diop,
Coastal Fisheries Institute, Louisiana State University, Baton Rouge, LA 70803
hdiop1@lsu.edu

Walter R. Keithly, Jr.,
Coastal Fisheries Institute, Louisiana State University, Baton Rouge, LA 70803.
Walterk@lsu.edu

Richard R. Kazmierczak, Jr.
Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge, LA 70803
Rkazmierczak@agcenter.lsu.edu

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# The Gulf of Mexico Grouper Fisheries: Heterogeneous Fleet and Expectations in Fishermen's Decision

Hamady Diop, Louisiana State University, hdiop1@lsu.edu
Walter R. Keithly, Jr., Louisiana State University, walterk@lsu.edu
Richard F. Kazmierczak, Jr., Louisiana State University, rkazmierczak@agcenter.lsu.edu.

## Abstract

Theory suggests that fishing effort would be allocated among various fishing grounds such that profit levels across grounds would be equal. Homogeneity among fishers as well as perfect information is assumed and profits are opportunistically increased by changing fishing locations. These assumptions have been shown empirically in some single fisheries where fishers and areas are relatively homogeneous. However, complexity arises when dealing with multispecies and multi-ground fisheries. Biological, economic, and regulatory measures further add to the complexity and complicate determining response by fishers to various factors. This study focuses on Gulf of Mexico fishermen's expectations about their revenues and risks when participating in the grouper fishery using handlines or longlines. Results indicated that expected revenues follow a seasonal and a spatial pattern. Fishermen using longline are risk averse while handliner are risk takers.

Keywords: grouper, production analysis, spatial analysis

## Introduction

The Gulf of Mexico Reef Fish Fishery Management Plan (RFMP) was one of the first FMP's submitted by the Gulf Council. Reef fish identified and managed under the original plan included 14 species of snappers (*Lutianidae Family*), 15 species of groupers (*Serranidae Family*) and three species of sea basses. Subsequent amendments to the Plan added five species of tilefishs (*Branchiostegidae Family*), two species of jacks (*Carangidae Family*), white grunt (*Haemulon plumieri*), red porgy (*Pagrus pargus*), and gray triggerfish (*Balistes capriscus*). The goal identified in the original Plan was "[t]o manage the reef fish fishery of the United States waters of the Gulf of Mexico to attain the greatest overall benefit to the Nation with particular reference to food production and recreational opportunities on the basis of maximum sustainable yield as modified by relevant economic, social, and ecological factors (p.2)." Pursuant to this goal, one of the primary objectives set forth in the plan was to rebuild declining reef fish stocks wherever they occur in the fishery. While encompassing a large number of species, because of its heavily overfished status, the majority of the Council's reef fish management activities have historically been red snapper oriented. More recently, management attention has been given to the grouper complexes. This attention reflects increasing conflicts among different segments of the industry as well as concern regarding the status of some of the individual species.

For the purposes of management, grouper stocks are divided into two groups. The first group, referred to as the shallow-water grouper, is managed in aggregate with an overall quota of 8.80 million pounds (gutted weight). The second group, the deep-water grouper, is also managed in aggregate with an overall quota of 1.02 million pounds (gutted weight). Three grouper species – red, gag, and black- comprise the majority of commercial shallow-water grouper landings. Longlines and vertical lines represent the primary gear types used to commercially harvest the shallow-water. While most vessels will fish with only one gear or the other during the course of a year, a limited amount of switching behavior is reported.

The majority of red grouper is harvested with longlines (approximately 80%) while the majority of black grouper is harvested with vertical lines. While the reason for this breakdown has not been established, industry sources suggest that gag and black grouper tend to aggregate and, hence are more susceptible to vertical lines. Red grouper, by comparison, does not tend to aggregate (except during spawning) and, hence, is not susceptible to vertical line gear; however, longline gear is ideally suited for harvesting this species. Overall, the proportion of red grouper taken by the longline sector has increased substantially since the mid-1980s.[1]

The National Marine Fisheries Service has recently declared red grouper as overfished and is also subject to overfishing. Furthermore, gag grouper, though not overfished, are approaching an overfished condition. In response the Gulf of Mexico Fishery Management Council (GMFMC) has "elected to revisit its overall strategy for managing groupers (Draft Amendment 18, no page number)." To this end, the Council, through Draft Amendement 18 to the RFMP, is considering a number of different options which would allow rebuilding of the stock. While a complete listing of these options is beyond the scope of this paper, they vary significantly in scope and include such measure as closed seasons/areas, individual species quotas, and limited entry.

As aptly stated by Holland and Sutinen (1999) "[u]nderstanding the response to fishers to changes in biological, economic, and regulatory conditions in fisheries is critical to designing management plans that will both protect the resources and provide economic benefits to fishers and consumers. This is particularly true in fisheries managed without direct controls on total effort or catch (p. 253)." The grouper fishery is, overall managed without direct controls on total effort and there is a paucity of information related to economic understanding of the Gulf grouper industry[2]. Without a more detailed understanding of the response of grouper fishers to changes in economic and regulatory measures, one can surmise that the options eventually chosen will be suboptimal when compared to those that would have been forthcoming if additional economic information was available. As such, the overall goal of this study is to model fishermen's expectations about their revenues and risks when participating in the Gulf of Mexico grouper fisheries using handlines and longlines. A subsequent goal is to assess how expectations on revenues, revenues variability and environmental factors are affecting fishing intensity. The modeling approach will be based on a single output technology approach.

Approach

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[1] In general, there are relatively few regulations regarding the harvest of grouper (other than size restrictions). One that should be mentioned though is the fact that longline vessels must operate outside the twenty fathom range east of Cape San Blas, Florida and 50 fathoms throughout the rest of the Gulf. Relatively little red grouper is harvested outside the fifty fathom range.

[2] An economic profile of the reef fish fishery can be found in Waters (1996). The profile, however, is not grouper specific and there is often insufficient information to determine grouper practices.

There exits few published studies on fishery choice and location (Bockstael and Opaluch, 1983, Eales and Wilen, 1986, Dupont, 1993, Ward and Sutinen, 1994). However, in the last four years, people are paying increased attention to the importance of spatial dimension in fishery (Holland and Sutinen, 1999, 2000, Curtis and Hicks, 2000, Hicks and al, 2004, Curtis and McConnel, 2004, Strand, 2004, Mistiaen and Strand, 2000, Smith, 2000, Wilen, 2000, 2004, Smith and Wilen, 2004, Fleming, 2000, Holland and al, 2004, Holland, 2004, Sanchirico, 2004, Dalton and Ralston, 2004, ). A Recent body of literature has added the gear choice selection to those models (Eggert and Tveterås, 2004). This current study will contribute to that new body of literature by modeling fishers' expectations about their revenue when participation in fisheries decisions are made. We have made some assumptions about participation by arbitrarily including in the analysis fishers who have a minimum of 20 percent of grouper species in their harvest. Two steps are required in the modeling process. The first step consists of estimating the Just-Pope production function using revenue per trip, area fished, seasonal components and vessel specific characteristics. In the second step the predicted revenues per trip and their variability, together with weather variables in a random parameters utility model which allows for heterogeneous risk preferences, are used to evaluate the fishermen participation in the grouper fisheries using the Poisson regression as in Smith (2004). The following section will describe both the Just-Pope (JP) production (1979) function and the Poisson model.

A. The Just Pope Production Function

Building on Eggert and Tveterås, (2004) work, this study will model fishermen's expectations about their revenues and risks when participating in the Gulf of Mexico grouper fishery. Specifically, a JP production function in the mean standard deviation framework will be estimated. We will hypothesize that expectations are formed on revenues when grouper fishery participants make their gear choices. We will also hypothesize that the production technology is of a single type output since the fishers have little influence on the by-catches once the choice of the gear and the target species are made. Revenues per boat on a given trip will generate unbiased results in a gear choice model when variable costs are independent of choices (Eggert and Tvesteras, 2004). This would be the case for example when similar amounts of fuel are consumed in targeting different species.
The Just Pope production (1979) function is generally defined as

$$y = g(x) + \mu = g(x) + h(x)^{1/2}\,\varepsilon$$

where *x* is a vector of *k* inputs, *g(.)* is the mean function and *h(.)* is the variance function and (.) is the exogenous production shock. Expected values of *y* is *g(x)* and

$$\operatorname{var}(y) = h(x)\sigma_{\varepsilon}^{2}$$

The production function exhibits its desirable properties with $g_x>0$ and $g_{xx}<0$. The risk factor is captured with *h(x)*. When the fishermen are risk averse, *h(x)* is negative. In contrast, a fisherman risk seeking behavior is associated with a positive *h(x).* When *h(x)* is constant, the model becomes an additive production uncertainty (Karagiannis, 1999) whereas an equality between *h(x)* and *f(x)* leads to a multiplicative production uncertainty with *y=f(x)(1+e)*. In the case of fisheries, the additive production uncertainty will be encountered when variability in catch is different from expected catch due to natural phenomena.

With limited gear switching in the fisheries, the focus should be on estimating separate production functions for the longlines and the handlines. Those functions should be characterized as single output technologies since fishers have little command on the amount of by-catches once they choose a gear and a target species. The mean production function for each gear will be specified as follows:

$$y_{it} = \alpha_j Effort_{it} + \beta_{ij} Effort_{it}^2 + \gamma_{gj} Effort_{it} * Vlength_i + \sum_{m=1}^{12} \theta_{mj} D_m + \sum_{i=1}^{z} \theta_{ij} V_i + u_{it}$$

where $y_{it}$ is the value of landings of the $i^{th}$ vessel from the $t^{th}$ trip, Effort is the total fishing gear soak time; *Vlength* is the vessel length in feet used as a proxy for capital stock, $D_m$ is a vector of monthly dummy variables and $V_i$ is a vector of vessel dummy variables that captures the vessel observable and unobservable characteristics. As in Eggert and Tveterås (2004) the interaction between effort and the capital stock variable will determine if larger vessels have higher fishing capacity when compared to smaller vessels. The variance function is assumed to be a special case of Harvey's (1976) and is specified as follows

$$\text{var}(u_{it}) = \exp(\delta_j Effort_{it} + \delta_{ij} Effort_{it}^2 + \delta_{gj} Effort_{it} * Vlength_i + \sum_{m=1}^{12} \delta_m D_m + \sum_{i=1}^{z} \delta_i V_i)$$

The predicted values of the mean revenues and the standard deviations from the Just Pope Production function are used as explanatory variables in the Poisson regression depicting participation in the fishery.

B. The Poisson Regression

The Poisson regression is generally specified as follows

$$\Pr(y = r) = \frac{\lambda^r e^{-\lambda}}{r!}, \text{ r=0, 1, 2…}$$

where $\lambda$ is the expected value of $y$. It is common to let $\lambda$ be a loglinear function of the $x$ variables (Allisson, 1999) such that

$$\ln(\lambda_t) = \beta_t x_t$$

In the participation regression, $y$ is the number of trips per vessel in a given month and $x$ represents mean revenues and variances per vessel predicted from the *Just Pope* production function. One of the characteristics of the Poisson model is that expected value of the dependent variable should equal to its variance ($\lambda_t$). In case of inequality, the model is qualified as overdispersed and a negative binomial regression would be more appropriate. The weather data includes wave heights. As in Smith (2002), they are included in the model to capture nonlinear participation responses to weather. It is expected that higher revenues will intensify fishing effort and adverse weather conditions will have negative impacts on fishing effort. The variance of the expected revenues will impact positively the fishing effort if fishers are risk takers and its expected sign will be negative if fishers are risk averse.

Data

The fisheries logbook data, collected by the National Marine Fisheries Service, contain information on fishing trips, area fished, fishing effort, and landings per species. Prices and vessel characteristics were provide by the NMFS and were merged to the logbook data. The database identifies 21 fishing areas (Figure 1) in the Gulf of Mexico, contiguous along the coast, where grouper fishermen operate. However, most of the fishing activities are located along the Florida coast between area 1 and 7; therefore our analysis will be restricted to those areas[3]. Six years of data covering year 1996 through 2001 were made available. The weather data were obtained from the National Buoy Data Center. While the logbook data were expressed on a trip basis, the weather data variables were monthly. The 1143 vessels using handlines as a main fishing gear averaged 37 feet in length; landed 300 pounds of groupers per trip with an associated dollars amount $721. Their trip lasted, about three days on average. In contrast, the average revenues made per trip by a longliner was about 6000 dollars. About 252 vessels reported activities using longline. Those vessels averaged about 45 feet in length. Their landing per trip is about 2600 pounds of grouper species and the trip length is about a week.

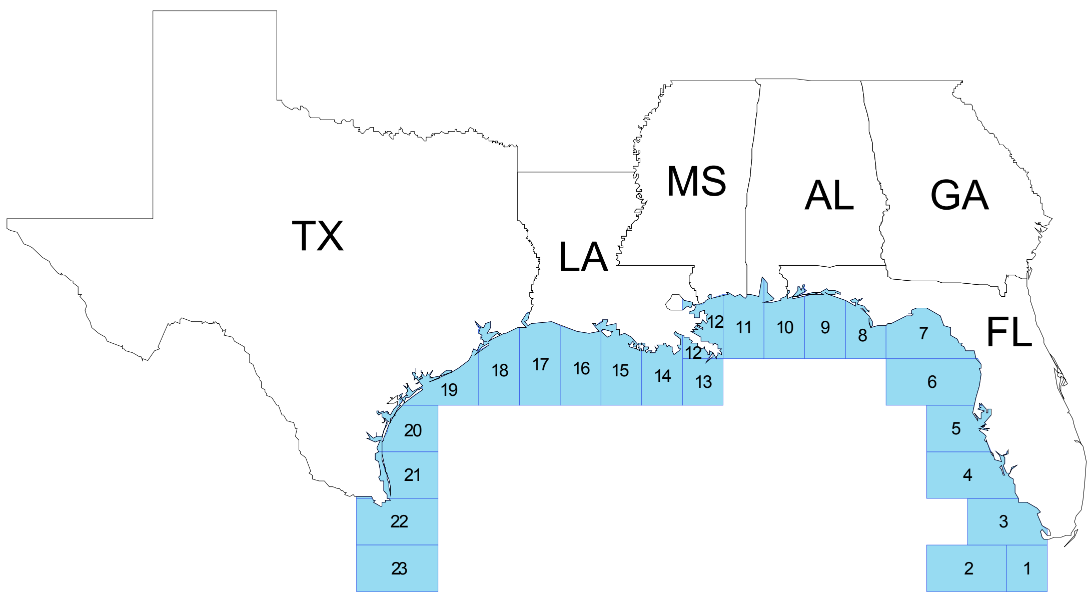


Figure 1: Gulf of Mexico Statistical Grid Map

Results and Discussion

We estimated the Just-Pope production function using SAS Proc MIXED. This procedure has three major advantages: a) it allows the data to be normally distributed; b) the means of the data are linear with respect to estimated parameters; and c) the variances and covariances of the data are unrestricted, which could allow high variability in the data. In our approach, we estimated a random parameter model with fixed effects and we assumed that seasonal, spatial as well as vessel effects could be allowed to affect randomly the variability in the data. The Poisson and

[3] The analysis was also conducted with areas 1 to 10 included and similar results as those presented in this paper were obtained.

Negative Binomial models were estimated using SAS Proc GENMOD. The results are discussed below.

Handlines

The covariance parameter estimates (Table 1) represent the random effects portion of the model. All variance components are statistically different from zero at the 5% alpha level indicating that revenues per trip vary by month and year. They also vary by vessel. There is more variability in revenue within vessels than within year and month. The ratio of the covariance estimate of vessels over covariance estimate of model residual is 62% indicating that a large variability in revenues per trip is associated with specific vessels characteristics. The fixed effect portion of the model (Table 2) indicates an intercept that is not statistically different from zero. This translates into a zero effect on revenues when all predictors are zero. Results also indicate that vessel that differ by one unit of effort will differ in revenue by 27.40-0.09*effort+0.19*vlength. The interaction between vessel length and effort is positive indicating that larger vessels have more capital stocks and therefore are likely to harvest more grouper and generate more revenues. We can also infer from the relationship that the marginal effort product is declining as fishing pressure is increased. The model also indicates that vessel characteristics, crew skills, engine power, vessel age, and special fishing equipments and other unobservable vessel characteristics are all important predictors of revenue per trip. Most of the fluctuations in revenues are observed in 1996-1997 and in 2000-01. A strong monthly seasonal variation in revenue is observed during June through February. There is also variability in revenues associated with visited areas (Figure 1).

Since our model estimates suggested that the Poisson regression results showed overdispersion (Table 3), we fitted our participation model using a negative binomial that correct for overdispersion. Fishers are found to consider both expected revenues and expected revenues variability when deciding to participate in the grouper fishery using the handlines. They are risk takers as the coefficient on the risk variable is positive indicating that higher variability in expected revenue are not deterrent of fishing activities and that they are associated with higher effort given the handline gear type. There is a positive non significant relation between wave heights and fishing activities. This could be that handliners have small boats and make shorter trips and therefore they have to fish more often to break even.

Longlines

The covariance parameter estimates indicate that revenues per trip vary by vessel (Table 1), month and year. There is also a large fluctuation in revenues within month and within vessels. About 252 vessels were reported, over the sample period, targeting the grouper species using the longlines. With the exception of 1998 and 2000, a fluctuation in revenues per trip is observed between years. Revenues per trip also vary from month to month and the most significant months are January, March, July, August, September and November. Fishers respond to economic incentives since expected higher revenues (Table 2) are associated with an increased number of trips. However this intensification in fishing effort is dampened by weather conditions such as wave height. These weather conditions combined with a declining number of fishing trips are associated with a high expected variance in revenues for specific areas which indicate that fishers using longlines are risk averse.

## Conclusion

The heterogeneity in fishers and vessels seem to be important indicators for fluctuation in revenues per trip and their variability. Month fished as well as areas visited are also important. Results also indicated that fishers consider both revenues and their variability when deciding to participate in the grouper fisheries using longlines or handlines. The current size of the statistical grid (1 minute) is not adequate for analyzing spatial movement of fleet since the boats are mostly small and a lot of movement can occur within a grid. An availability of finer geo-referenced data in the future will permit the investigation of fleet spatial movement in response to biological, environmental and economics shocks.

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Table 1: Covariance Parameter Estimates Associated with Just Pope Revenues per Trip Function

| | Handline | | | Longline | | |
|---|---|---|---|---|---|---|
| Covariance Parameters | Ratio | Estimates | Value of Z(a) | Ratio | Estimates | Value of Z(a) |
| Vessel | 0.62 | 718145 | 18.63* | 0.64 | 11240149 | 9.01* |
| Year | 0.06 | 66044 | 1.57** | 0.10 | 1729442 | 1.56** |
| Month | 0.02 | 22818 | 2.29* | 0.03 | 598186 | 2.23* |
| Area | 0.02 | 26818 | 1.54** | 0.01 | 153437 | 1.24 |
| Residual | 1.00 | 1156573 | 113.00* | 1.0 | 17670968 | 60.17* |

(a) * = 5% significance level; ** = 10% significance level.

Table 2: Parameters Estimates of the Just-Pope Revenues per Trip Function

| | Handlines Estimates | T-values | Longlines Estimates | T-values |
|---|---|---|---|---|
| <u>Mean Revenues</u> | | | | |
| <u>Fixed Effects</u> | | | | |
| Intercept | 151.89 | 1.14 | 4726.74 | 7.23* |
| Fished | 27.40 | 17.03* | 27.64 | 5.54* |
| $Fished^2$ | -0.09 | -21.80* | -0.02 | -12.30* |
| Fished*Vlength | 0.19 | 4.80* | 0.01 | 0.05 |
| | | | | |
| <u>Random Effect</u> | | | | |
| Minimum (a) | -1558.99 | -3.98* | -4868.53 | -3.70* |
| Maximum | 6288.22 | 11.10* | 13019 | 13.59* |
| Year 1996 | -303.65 | -2.85* | -1486.93 | -2.71* |
| Year 1997 | -253.54 | -2.39* | -1547.11 | -2.82* |
| Year 1998 | 2.27 | 0.02 | -323.44 | -0.59 |
| Year 1999 | -24.18 | -0.23* | 1191.61 | 2.17* |
| Year 2000 | 245.65 | 2.32* | 865.90 | 1.58 |
| Year 2001 | 333.44 | 3.14* | 1299.96 | 2.36* |
| January | 278.34 | 5.65* | 1195.75 | 4.31* |
| February | 32.03 | 0.64 | 292.04 | 1.05 |
| March | 69.51 | 141 | 663.58 | 2.41* |
| April | 52.46 | 1.08 | 322.85 | 1.18 |
| May | -9.41 | -0.20 | 28.37 | 0.10 |
| June | -210.96 | -4.35* | -425.73 | 1.56 |
| July | -210.65 | -4.30* | -1332.13 | -4.85* |
| August | -167.18 | -3.40* | -921.73 | -3.36* |
| September | -122.05 | -2.46* | -891.49 | -3.19* |
| October | 103.45 | 2.10* | 66.78 | 0.80 |
| November | 103.22 | 2.11* | 732.16 | 2.68* |
| December | 81.23 | 1.65** | 268.53 | 0.99 |
| Area 1 | -191.47 | -2.36* | -157.24 | -0.44 |
| Area 2 | -153.09 | -1.94* | -379.83 | -1.62 |
| Area 3 | -131.65 | -1.70* | -13.50 | -0.06 |
| Area 4 | 44.30 | 0.62 | 461.93 | 2.32* |
| Area 5 | 80.26 | 1.18 | 207.28 | 1.10 |
| Area 6 | 145.10 | 2.14* | 277.08 | 1.31 |
| Area 7 | 206.55 | 2.87 | -395.70 | -1.48 |
| Number of Observations | 26616 | | 7480 | |
| Number of Vessels | 1143 | | 252 | |

(a) Since dummy variables are included in the model to capture observable and non-observable vessel characteristics, only the largest and the smallest vessel coefficient estimated for the dummy variables are listed in the table

Table 3: Fishery Participation Estimates from a Negative Binomial Regression

| Variables | Handline | | Longline | |
|---|---|---|---|---|
| | Coefficient Estimates | Chi-Square | Coefficient Estimates | Chi-Square |
| Intercept | 1.0315 | 26.09* | 3.1728 | 268.94* |
| Revenues | 0.0002 | 4046.85* | 0.0001 | 1065.35* |
| Revenues variance | 0.0260 | 107.08* | -0.0225 | 82.63* |
| Wind Speed | 0.0010 | 0.26 | -0.0071 | 13.89* |
| Dispersion | 0.3138 | | 0.08 | |

(*) Significant at 5% alpha level; (**) Significant at 10% alpha level.