SPATIAL ANALYSIS WITHIN AN ECONOMIC FRAMEWORK FOR THE U.S. GULF OF MEXICO GROUPER FISHERY

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ABSTRACT

Theory suggests that fishing effort would be allocated among various fishing grounds such that profit levels 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 provides a spatial analysis of the U.S. Gulf of Mexico grouper fishery and lays some grounds for future studies on fleet dynamics, location choice, and potential impacts to commercial Gulf of Mexico grouper fishermen behavior under varying economic and regulatory conditions. The study is timely in that red grouper, one of the primary species targeted by commercial fishermen, has recently been declared as overfished and alternative regulations are currently being evaluated to rebuild the stock.

Keywords: grouper, production analysis, spatial analysis

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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 was to rebuild declining reef fish stocks wherever they occurs 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 9.8 million pounds. The second group, the deep-water grouper, is also managed in aggregate with an overall quota of 1.6 million pounds. Three grouper species – red, gag, and black- comprise the majority of commercial shallow-water grouper landings. Longlines and handlines 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. (Poffenberger, John. National Marine Fisheries Service, personal communication).

Based on logbook data, 1121 vessels reported grouper activities in 2001; 177 of those vessels reported use of longlines. The longline vessels reported 1986 trips in 2001, typically lasting up to a week in length. The handline vessels, by comparison, generally make trips lasting only a couple of days in length. While the vast majority of the handline vessels harvest less than 500 pounds of grouper per trip, approximately one half of the longline vessels report landings which suggest more than 2500 pounds of grouper per trip, average.

The majority of red grouper is harvested with longlines (approximately 80%) while the majority of black grouper is harvested with handlines. While the reason for this breakdown has not been established, industry sources suggest that gag and black grouper tend to aggregate and, hence are susceptible to handlines. Red grouper, by comparison, does not tend to aggregate (except during spawning) and, hence, is not susceptible to handline 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)." To this end, the Council, through Draft Amendment 18 to the Reef Fish Management Plan (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 proposal, 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.

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. 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' expectation about their revenue when participation in fisheries decisions is made. 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 are used to evaluate the fishermen participation in the grouper fisheries using a 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 fisheries. Since revenues generate unbiased results in a gear choice model when variable costs are independent of choices, the focus will be on revenues rather than costs per boat on a given trip. Unbiased results would occur for example when similar amounts of fuel are consumed in targeting different species. To conduct the analysis, we will estimate a JP production function in the mean standard deviation framework. We will hypothesize that expectations are formed on revenues when grouper fishers make their decisions on gear choices. 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

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

The production function exhibits the desirable properties of $g_x>0$ and $g_{xx}<0$. The risk factor is captured with *h(x)*. When the fishermen is risk averse, *h(x)* is negative. In contrast, a fishermen 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 control on the amount of by-catches once they choose a gear and a target species. The mean production function for each gear is 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 monthly dummy variable and V_i is a vessel dummy variable. As in Eggert and Tveterås (2004) the interaction between effort and the capital stock variable will determine if larger vessels have higher fishing capacity 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 λ is the expected value of y. It is common to let λ 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 fishing days per vessel in a given month and x represents mean revenues and variances per vessel predicted from the *Just Pope* production function. Weather data considered for the analysis included wave height, sea surface water temperature and wind speed. However, only wind speed was included in the final model due to significant missing values associated with the other two variables. As in Smith (2002), the wind speed is 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 obtained from other sources. The database identifies 21 fishing areas (Figure 1) in the Gulf of Mexico, contiguous along the coast, where grouper fishermen operate. Six years of data covering year 1996 through 2001 were included in the analysis. Additional 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 vessels using handlines as a main fishing gear averaged 37 feet in length, fished about 8 days a month, landed 950 pounds of total reef fish of which 26 percent during the six-year period were groupers. The average revenues made per trip by a handliner is about $1900 of which 28 percent is associated with grouper species. In contrast, vessels using longline as a main fishing gear averaged about 45 feet in length and fished about 12 days a month. Their landing per trip is about 3450 pounds of reef fish of which 69 percent is grouper species. The estimated value of landings is about $6100 and 83% of this value is associated with grouper species. The estimation procedure was carried out using SAS PROC MIXED and LIMDEP.

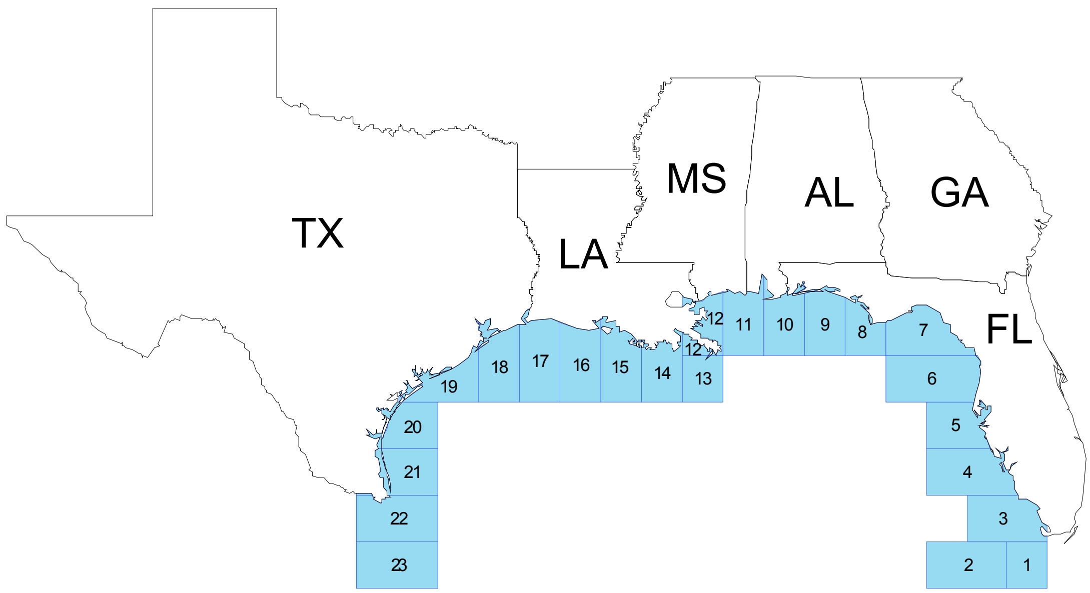

Figure 1: Gulf of Mexico Statistical Grid Map

Results and Discussion

Handlines

The covariance parameter estimates (Table 1) represent the random effects portion of the model. The larger those covariances are, the more variability is observed in the data. Results show that 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 area and vessel. There is more variability in revenue within area and month than within year and vessels. The variance in revenue per trip component of 989466 is more than 8 times higher than the variance component in revenue per trip within areas (113574) and much higher than the variance in revenue within months. The fixed effect portion of the model (Table 2) displays 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 vessels that differ by one unit of effort will differ in revenue by 26.908-0.0327*effort-0.13*vlength. The interaction between vessel length and effort is negatively signed indicating that larger vessels are less likely to use handlines as fishing gear and also receive less revenues with the handlines. We can also infer from the interaction that effort changes given vessel length. About 1604 vessels over the sample data were reported using handlines. The model indicates that among those vessels, 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 fluctuation in revenues is observed between1996 and 1997 and in 2001. A strong monthly seasonal variation in revenue is observed during the summer months (June through September) and in January. The areas in which revenues per trip fluctuates the most are areas 3 through 7 (Figure 1), areas 10 to 14 and areas 16 to 18. Due to space limitation, only the largest and the smallest vessel specific fixed effect are displayed in Table 2.

Fishers consider both revenue and revenue variability when deciding to participate in the grouper fishery using the handlines. Results indicate that harsh weather conditions as measured by high wind speed coupled with higher variability in expected revenues per area fished are not deterrent of fishing activity. Therefore fishers using handlines can be qualified as risk takers as the coefficients on the risk variable and weather variable are positive (Table 3). Results, also, show that increases in revenues per trip are associated with more fishing days.

Longlines

The covariance parameter estimates indicate that revenues per trip vary by vessel, month and areas. There is also a large fluctuation in revenues within month and within vessels. About 289 vessels, over the sample period, reported fishing groupers using longlines. With the exception of 1998 and 2000, a flux in revenues is observed within years. Revenues per trip also vary from month to month and the most significant months are July through September and November through February, Heterogeneity in vessels unobserved and observed characteristics is also a significant predictor of revenues per trip.

In contrast with the handliners, longliners respond differently to economics incentives and weather conditions. They are risk averse since variability in expected revenues lessens effort by dampening days at sea. However, longliners extend their days at sea when high expected revenues are associated with visited areas.

Conclusion

The overall goal of this study was 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 was to assess how expectations on revenues, revenues variability and environmental factors are affecting fishing intensity. The heterogeneity in fisher skills and other unobservable vessel characteristics seem to be important indicators of 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. Those decisions are influenced by existing regulations. Weitzman (2000) argued, given the risk and uncertainty associated with fishing, that a landing tax, which can be a correction for fishers' tendency to over-exploit a fishing ground, always performs better than an ITQ solution. Since our results single out the areas and the months in which the fishers are most active, it would be interesting to see how landing tax can be used to modify fishers' behavior in those area and months and compare the outcome of this policy to area closure or marine protected area policy which is a current policy tool for some managed grouper species. Further analysis should focus on entry-exit and vessel movements from one area to another. The current size of the statistical grid (1 minute) is not adequate for this type of analysis since the boats are mostly small and a lot of movement can occur within a grid which won't be captured using the current analytical framework. Additional analysis should focus on the coastal Florida waters where all the grouper fishing activities are concentrated.

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Tables, Figures, and Appendices.

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

	Longlines			Handlines		
Covariance Parameters	Ratio	Estimate	Value of Z	Ratio	Estimate	Value of Z
Vessel	0.502	8628695	10.99*	0.445	440458	23.33*
Year	0.066	1130926	1.56**	0.024	23975	1.57**
Month	0.031	535513	2.26*	0.016	16016	2.30*
Area	0.176	3026423	2.80*	0.115	113574	3.03*
Residual	1.000	17173865	70.81*	1.000	989466	153.57*

* Significant at 5 percent alpha level; ** significant at 10 percent alpha level

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

	Handlines	Longlines
Mean Revenues		
Fixed Effects		
Intercept	-86.594	2195.37*
	(106.53)	(655.07)
Fished	26.0908*	28.9559*
	(0.7838)	(4.25)
$Fished^2$	-0.0327*	-0.0195*
	(0.0013)	(0.001)
Fished*Vlength	-0.1313*	0.0251
	(0.018)	(0.09)
Random Effect		
Minimum	-1163.98	-4819.49
	(347.24)	(500.80)
Maximum	7869.94	11115
	(145.50)	(502.12)
Number of Observations	48679	10332
Number of Vessels	1604	289

* Significant at 5 percent alpha level; ** significant at 10 percent alpha level

Table 3: Fishery Participation Estimates

Variables	Handlines		Longlines	
	Coefficient Estimates	Marginal Effects	Coefficient Estimates	Marginal Effects
Intercept	1.8934*	15.536*	2.3614*	29.023*
	(0.0086)	(0.00769)	(0.0132)	(1.709)
Revenues	0.509E-04*	0.0004*	0.307E-04*	0.376E-03*
	(0.52E-06)	(0.466E-05)	(0.337E-06)	(0.435E-05)
Revenues variance	0.0004*	0.0034*	-0.644E-03*	-0.791E-02*
	(0.00005)	(0.0005)	(0.529E-4)	(0.665E-03)
Wind Speed	0.0035*	0.0287*	0.575E-03	-0.707E-02
	(0.0004)	(0.0037)	(0.504E-03)	(0.652E-02)

* Significant at 5 percent alpha level; ** significant at 10 percent alpha level