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Economic Benefits of Management Reform in the Gulf of Mexico Grouper Fishery: A Semi-parametric Analysis

Quinn Weninger

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Economic benefits of management reform in the Gulf of Mexico grouper fishery: A semi-parametric analysis

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Abstract

This paper uses a semi-parametric empirical model to estimate the economic benefits of adopting a property rights-based management program in the Gulf of Mexico grouper fishery. The analysis predicts that a rights-based fleet will be comprised of fewer, more cost efficient boats than under the current controlled access management program. Results indicate that in the year of our data, 1993, the smaller, more productive fleet could harvest the allowable reef fish catch at a cost saving of $2.92-$7.07 million, 12-30% less than under controlled access management. Recent tightening of controlled access regulations suggest that the benefits from management reform could be even larger in the current day fishery.

Key Words: Individual fishing quotas, semi-parametric efficiency analysis, fleet restructuring.

JEL Classification: Q2, D2

*Funding from the National Marine Fisheries Service is greatly appreciated. Please send correspondence to the Department of Economics, 260 Heady Hall, Iowa State University, Ames, IA, 50011-1070, or email weninger@iastate.edu.

1 Introduction

Commercial fishermen in the eastern Gulf of Mexico reef fish fishery target primarily shallow grouper species, deep water groupers and other reef fish. Current management measures in the primarily *grouper* fishery include a license limitation, annual catch quotas for heavily targeted species, per trip catch limits, minimum size limits, area/gear restrictions, and season closures.[1] Despite extensive restrictions on harvesting activities, the National Marine Fisheries Service classifies several high-value and large-volume reef fish species as overfished (red, gag, and yellowedge groupers). Furthermore, recurrent adjustment to regulations and conflicts between gear types—vertical hook and line, long lines and fish traps—over increasingly diminished resource stocks subsumes time and efforts of regulators charged with protecting fish stocks. In the wake of these problems, the Gulf of Mexico Fisheries Management Council and industry have begun an evaluation of alternatives to the current controlled access management approach which might improve economic and biological conditions in the fishery.[2]

One alternative being considered is individual fishing quotas (IFQs).[3] IFQs grant a right to harvest specified quantities of grouper and other reef fish species during each fishing season. Market-based incentives implicit in IFQs promise to increase the economic performance of harvesting operations, stabilize the economic and regulatory environment and improve safety for fishermen. Substantial gains in economic performance, i.e., harvesting efficiency, are expected to emerge under IFQ management (Gulf of Mexico Fishery Management Council, 2007). However, the actual efficiency gains cannot be fully observed until adjustments to harvesting practices and fleet composition that take place in response to the economic incentives implicit in the IFQ program are completed. This paper predicts changes in fleet structure and per-vessel harvesting activities that are expected under the

[1] Eight major grouper species are targeted in the eastern region of the Gulf of Mexico reef fish fishery: black, gag, scamp, yellowedge, warsaw, and snowy groupers, and speckled hind.

[2] Groupers are a popular target of recreational fishermen. In 2004 the recreational sector exceeded its target quota for red grouper by 254%, prompting a call for tightened restrictions on recreational fishing (see Secretarial Amendment 1 to the Fisheries Management Plan for the Reef Fish Resources of the Gulf of Mexico). The recreational fishery is not considered in this paper.

[3] Amendment 29 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico considers the merits of several management alternatives including, the elimination of latent permits, a buyback or buyout program, permit endorsements, an individual fishing quota program, and an individual transferable effort quota program.

proposed IFQ program.[4] Based on these predictions, an estimate of the economic benefits from replacing the current controlled access management program with IFQs is derived.

Current regulatory and economic conditions in the grouper fishery suggest several potential sources for improved harvesting performance (Gulf of Mexico Fishery Management Council, 2007). First, the fishery is considered to have excess harvesting capacity. Economic incentives implicit in IFQ programs align fleet harvesting capacity with target harvest levels set by managers, which can result in economics of scale and possibly economies of scope. Knowledge of the extent of fleet downsizing is necessary to determine how significant these economies will be. Second, efficiency gains are expected as tradable harvest permits gravitate to the most productive vessel operations in the fleet. Lastly, controlled access regulations such as per-trip catch limits and seasonal closures, currently used to prevent overfishing, will be eliminated yielding further cost savings.

The conceptual approach for estimating the anticipated cost savings from adopting IFQs in the grouper fishery follows Weninger and Waters (2003). Currently available data is analyzed to measure the key sources of harvesting inefficiency under the current management program. The results are then used to predict vessel-level harvesting activities and equilibrium fleet structure expected to emerge under IFQs.

In this paper a semi-parametric empirical model recently developed by Simar and Wilson (2007) is used to analyze inefficiency under current management. The semi-parametric model offers several advantages over single-step data envelopment analysis.[5] The first step employs non-parametric methods (data envelopment analysis) to derive vessel-level efficiency measures. Bootstrap procedures correct for bias inherent in finite sample non-parametric models (see Simar and Wilson, 2000). Non-parametric models avoid potential functional form bias, and provide a convenient framework to examine factors such as scale

[4] Weninger and Waters (2003) study the potential effects of adopting rights-based managment in the northern region of the reef fish fishery. Dupont (2000), Squires and Kirkley (1995, 1996), and Squires, Alauddin and Kirkley (1994) provide *ex ante* estimates of the potential gains from tradable harvest permits. Studies examining the performance of existing programs are increasingly available, e.g., Grafton, Squires and Fox (2000).

[5] Single-step nonparametric frontier models have been used extensively to study economic performance and capacity utilization in commercial fisheries (e.g., Kirkley et al., 2002; Weninger and Waters, 2003; Walden, 2006). Färe et al. (1994), and Coelli et al. (1998) provide exhaustive reviews of nonparametric frontier models.

inefficiency which is thought to be significant under controlled access regulation.[6] The empirical model includes a second-stage parametric analysis which links the measured performance of individual vessel operations to environmental factors.

The added information from the second stage may be particularly useful for managers and industry concerned with the broader impacts of fisheries management reform. For example, our stage two results link harvesting performance under controlled access management to observable vessel characteristics, skipper experience, gear types (longline, vertical line and fish traps) and the port from which vessels fish. The relationship between our environmental factors and vessel performance provide key insights into fleet adjustment expected in the switch to IFQ management. Results find that the IFQ-regime fleet will likely be dominated by mid-sized vessels operated by mid-career captains, whereas fleet restructuring is not predicted to vary significantly across gear types or geographical regions of the fishery. This information can guide policy makers concerned with the transition to the new equilibrium conditions in the fishery. In particular, vessel operations deemed most likely to be impacted by management reform can be the focus of policies designed to ease the transition caused by management reform.

The data analyzed in this paper is from a stratified sample of 149 vessel owner operators who landed reef fish (primarily groupers) during the 1993 season in the eastern Gulf of Mexico. While somewhat dated, this data provide a *view* of vessel harvesting activities in the absence of many of the recently tightened controlled-access regulations. Since controlled access regulations will be removed under IFQs, the harvesting practices, i.e., input and output choices for our 1993 sample, can provide a reasonable representation of vessel activity expected under IFQ management. The downside is that 1993 data is conditioned on stock abundance and other economic conditions that prevailed in the fishery at the time. The implications of the results for the current day management is interpreted with this caveat in mind.

The analysis identifies two factors as the key sources of economic gains under an IFQ management program. First, economies of scale in production are expected as the aggregate commercial harvest is consolidated onto fewer boats. Second, economies in the form of pure

[6] See Kumbhakar and Knox Lovell (2000) for a review of parametric methods for efficiency analysis.

technical efficiency gains are expected as the bulk of the harvesting activities are carried out by the most efficient vessel operations in the fleet. Results indicates that the IFQ-regime fleet will consist of roughly 200-250 vessels. In comparison, 990 vessels reported positive landings in the eastern Gulf reef fish fishery in 1993. While many of these vessels are part time commercial operations who landing small quantities of reef fish, the extent of fleet downsizing that is expected under IFQs is significant.

Calculations reveal further that fleet downsizing and redistribution of the catch to productive boats will reduce variable harvesting costs by as much as 30% in the fishery; a $7.07 million cost saving is predicted in the year of the data (all values are in 1993 dollars). Additional fixed cost savings, which are more difficult to quantify due to the part time nature many active vessels, are also expected.[7] While direct extrapolation of the 1993 cost savings estimates is not possible, the results indicate that significant cost savings are available in the grouper fishery under an IFQ management program. Given the current regulatory environment which proposes tighter per-trip catch limits and quotas on more grouper species, it is likely that our results understate the benefits of management reform in the current day fishery. Overall, the results suggest that IFQs represent an attractive alternative to the current controlled access management program for the grouper fishery.

The next section introduces a conceptual model of harvest efficiency and fleet structure in an IFQ-managed fishery. Section 3 describes the data and empirical methodology. Results are presented in Section 4. Section 5 predicts vessel harvesting activities, fleet structure and harvest costs expected under IFQ management. A summary and concluding remarks follows in Section 6.

[7] Retiring redundant underutilized vessel capital saves resources required to maintain capital in working order. Commercial fishing vessels often participate in multiple fisheries using multiple gear types each year. Lacking data on total participation, it is conceptually and empirically difficult to allocate maintenance costs across fisheries.

2 Model of harvesting efficiency

Consider a representative fisherman who allocates inputs $x \in \Re_+^N$ to produce outputs $y \in \Re_+^M$ during a single fishing season. Feasible input-output combinations are given as;

$$T = \{(x, y) |\ x \text{ can produce } y\}. \tag{1}$$

T is assumed to be a closed, and convex set. The output directional distance function (ODDF) provides a convenient functional representation of feasible input/output combinations;

$$\overrightarrow{D}(x, y; g_y) = \max\{\beta \in \Re | (x, y + \beta g_y) \in T\}, \tag{2}$$

where $g_y \in \Re_+^M$ ($g_y \neq 0_M$) is a directional vector. The ODDF gives the maximal translation of the output y in the reference direction g_y that keeps the (translated) output in the set T. The ODDF directly measures output-oriented technical efficiency in the sense that when $\overrightarrow{D}(x, y|g_y) = 0$, no feasible translation of the output vector y is possible, whereas $\overrightarrow{D}(x, y|g_y) > 0$ indicates that y is located in the interior of T. Frontier output is calculated as $y + \overrightarrow{D}(x, y|g_y)g_y$. Chambers, Chung, and Färe (1996) and Färe and Grosskopf (2000) provide additional discussion of directional distance functions.

The more familiar Shephard (1970) output distance function is a special case of the ODDF. The Shephard output distance function is

$$D_o(x, y) = \inf_{\theta}\{\theta : (x, y/\theta) \in T\}. \tag{3}$$

At directional vector $g_y = y$, it can be shown that $\overrightarrow{D}(x, y|y) = D_o(x, y)^{-1} - 1$.

It will be convenient to work with the Farrell measure of output technical efficiency, which is the inverse of the Shephard output distance function. The relationship between the Farrell measure, which we will denote as $\delta(x, y)$, the Shephard output distance function, and the ODDF is as follows (see Färe and Grosskopf, 2000):

$$\delta(x, y) = D_o(x, y)^{-1} = 1 + \overrightarrow{D}(x, y|y).$$

We turn next to the implications of harvesting efficiency for equilibrium fleet structure in an IFQ fishery.

2.1 Fleet structure under IFQ fishery management

Under IFQ management, tradable harvest permits, which sum to the target total harvest level for each fish species, are distributed to fishermen. Let Y_i denote the total allowable harvest for species $i = 1, ..., M$ fish. With frictionless permit trading, a per period lease prices λ_i will emerge for each permitted species. We assume that active fishing firms purchase or sell harvest permits and purchase factor inputs to maximize profits;

$$\pi(r, w) = \max_{(x,y \geq 0)} \{ry - wx\},$$

where w denotes a vector of unit input prices, and r is the net price for fish. Letting p denote the vector of dockside prices, the net fish price is $r = (p - \lambda)$.

It can be shown that the following inequality holds (Chambers et al., 1998),

$$\begin{aligned} \pi(r, w) &\geq ry - wx + r\overrightarrow{D}(x, y|g_y)g_y \\ &\geq r\left(1 + \overrightarrow{D}(x, y|y)\right) y - wx, \end{aligned}$$

where maximum profit is given by

$$\pi(r, w) = \max_{(x,y) \geq 0} \left\{ry - wx + r\overrightarrow{D}(x, y|g_y)g_y\right\}. \tag{4}$$

Expression 4 indicates that profits are maximized only if activity (x, y) is located on the boundary of the feasible set T, or in other words, if $\overrightarrow{D}(x, y|g_y) = 0$.

Assuming that all permit lease prices are strictly positive, equilibrium conditions under the IFQ management program are given as,

$$\sum_{k=1}^{K^*} y_i^k = Y_i \qquad i = 1, ..., M \tag{C1}$$

$$K^* = \arg\max_{K} \{\sum_{k=1}^{K} r^* y^k - wx^k\} \tag{C2}$$

Condition C1 and C2 simultaneously determine equilibrium lease prices and the number of harvesting firms, denoted K^* that are active in the fishery under the IFQ program. Harvesting firms and vessel operations will hereafter be treated synonymously.

Condition C1 states that for each species the total catch of the fleet must equal the total allowable harvest, which is assumed to be set exogenously by the fishery management authority. Condition C2 states that the K^* active vessel operations must attain the largest overall (net) harvesting profits, conditional on the available harvest $Y_1, .., Y_M$. Notice that condition C2 explicitly allows for inefficiency to persist under the IFQ program. That is,

$$r^* y^k - w x^k = \pi(r^*, w) - r^* \overrightarrow{D}(x^k, y^k | g_y) g_y,$$

so that active firms may operate in the interior of T. The condition for equilibrium however does suggest that no inactive vessel can design a harvest plan and profitably enter the fishery. The implication is that active vessels must be the *best* at exhausting available production economies, e.g., economies from adjusting the scale and scope of operation and output technical efficiency.

In the context of the ODDF measure of efficiency, active vessels must attain the smallest possible value for $\overrightarrow{D}(x^k, y^k | g_y)$. If this were not the case then some redistribution of harvesting permits among active and inactive vessel operations could increase net harvesting profits in the fishery. Gains from permit trading would exist, which contradicts the equilibrium condition. Lastly, notice that because the profits are evaluated at the net price $r^* = p - \lambda^*$ condition C2 also ensures that the maximum available resource rent is generated from the total allowable catch levels set by the manager.[8]

The empirical goal of the paper is to identify the equilibrium fleet configuration, and the per vessel activity levels which satisfy conditions C1 and C2. Given an estimate of K^* and activity levels (x^k, y^k) for vessels under the IFQ management regime, estimates of economic performance, benefits relative to the current regulatory conditions in the fishery, readily emerge. The next section describes the data and empirical approach used for this purpose.

[8] A dynamic bioeconomic model could be used to identify the resource rent maximizing values fot $Y_1, ..., Y_M$ (Clark, 1990).

3 Background, data, and estimation

The reef fish fishery in the Gulf of Mexico is a complex of bottom-dwelling species consisting of red, black, yellowedge, gag, warsaw and other species of groupers, amberjacks, triggerfish, porgies, tilefish, and red, vermilion, and other snapper species. Vertical hook and lines, longlines and fish traps are the main gear types used in the year of our data, 1993. Managers and industry have adopted a convention of dividing the Gulf of Mexico reef fish fishery into northern and eastern regions. The northern region extends from Panama City, Florida west along the Texas shore to Mexico. Red snapper is the predominate (by volume and value) species targeted in the northern region. The analysis of this paper is focussed on the eastern region of the reef fish fishery which extends from Panama City, Florida east and south along the Florida coast to the Florida Keys. Because grouper species are the main target, the eastern Gulf reef fish fishery is often referred to as the *grouper fishery*.[9]

There are 15 species of grouper managed by the Reef Fish Fisheries Management Plan. The main species by harvested volume and economic value are Red, Gag and Black grouper, which are part of a shallow water complex, and Yellowedge grouper which is a deepwater grouper species. A host of other reef fish species are also harvested. In the year of our data, 1993, regulations used to control fishing pressure included vessel licenses, and minimum size restrictions for most species of shallow water groupers. Long line fishing gear was not permitted in some areas.

Data were gathered from two sources: a stratified survey of vessel owner/operators that was conducted for the 1993 harvest season (Waters, 1996 provides a detailed description of the data and survey design), and National Marine Fisheries Service log book records. The survey elicited cost and other information through personal interviews from 196 vessel operators, of which 150 harvested reef fish in the eastern Gulf region. National Marine Fisheries Service Log Book reporting system records trip-level information on harvest quantities, trip length, and the number of crew members on board the vessel.

The sample vessels harvested 4.417 million pounds of fish in 1993 with over 90 different species represented. While the number of species is large, a much smaller group make up

[9] Weninger and Waters (2003) analyze the benefits of adopting a rights-based management program in the northern Gulf reef fish fishery using standard non-parametric (data envelopment analysis) methods.

the bulk of the catch. Red grouper represents the largest component accounting for 43.4% of the total, vermilion snapper accounts for 13.0%, black grouper (7.3%), sharks (4.9%), grunts (4.8%), gag grouper (4.5%), greater amberjack (2.9%) and yellowedge grouper (2.8%) are also important.

Tractability requires that individual reef fish species be aggregated to form output groups. Feedback from grouper fishermen suggests that three output groups are appropriate based on similarity in harvesting practices, e.g., fishing locations, depths, bait, and capture methods, used to harvest the species within each group. Harvested quantities within each output category are aggregated linearly. The aggregation procedure assumes that optimal input choices and aggregate output levels can be chosen independently of the mix of species within each output category. The harvest technology is thus assumed to exhibit weak output separability. Linear aggregation implies a constant rate of transformation among species within each output group.[10]

The first output group, y_1, is made up primarily of shallow water groupers including red, gag, black, yellowfin and yellowedge grouper. Scamp, red and rock hind, and shark species are also included in y_1.[11] The second output category, y_2, consists primarily of deep water groupers including yellowedge, misty and warsaw groupers, plus speckled hind, golden, blueline and other tile fishes. The third output category consists of all non-reef fish such as king mackerel, yellowfin tuna, bonito, and wahoo. Hereafter, outputs y_1, y_2, and y_3, are referred to as shallow water groupers, deep water groupers and non-reef fish, respectively.

Shallow water groupers make up 88.1% of the sample vessel catch. Deep water groupers comprise 5.7% of sample vessel catch, and non-reef fish represent 5.0%. The two main variable inputs for reef fish vessels are labor, measured as the total number of captain plus crew days at sea, and fuel, which is measured as total gallons burned. The labor input is denoted x_1 and the fuel input as x_2. Other variable inputs are ice used to preserve harvested fish, bait, and lost fishing gear. It is assumed that these inputs are used in proportion to

[10] These assumptions are consistent with fishing practices as described to us by grouper fishermen. Nonetheless, it should be noted that output aggregation could bias the results that follow.

[11] Discussion with fishermen indicated that shark species are harvested using similar methods and are found a similar depths as shallow water groupers. Sharks make up a small component (5.4%) of the first output category.

	Mean.	Std. dev.	Min..	Max.
Shallow water groupers (y_1)	27.01	29.97	0	133.62.
Deep water groupers (y_2)	1.67	6.20	0	61.79.
Non-reef fish (y_3)	0.34	0.96	0	6.98
Total Catch	29.02	30.39	0.13	133.75
Trips from Port	13.08	11.93	1	77
Days at Sea	63.58	53.86	1	256
Labor (x_1)	191.75	175.63	1	802
Fuel (x_2)	3,200.32	3,403.76	42	20,000
Capital services (x_3)	2,700.87	2,555.22	24	13,568
Vessel Length (feet)	40.66	10.80	20	73

Table 1: Descriptive Statistics for 1993 Reef Fish Vessels. Harvest quantities are thousands of pounds, labor is in units of worker days at sea, fuel is in gallons, and capital services is in vessel foot days at sea. There are 149 observations.

the pounds of harvested fish. Ice, bait and lost gear costs are incorporated in the analysis below by adjusting the output price for fish.

Table 1 reports sample descriptive statistics. Notice that the composition of species harvested, and the scale of operation, measured by total catch and days at sea, varies widely across sample vessels. In all, 149 vessels harvested shallow water groupers; 74 harvested deep water groupers and 91 harvested non-reef fish. The number of trips taken ranges between 1 and 77. Days at sea range between 1 and 256. Variation in vessel capital is also indicated; the average vessel length is 40.66 feet, the range in the vessel length is between 20 and 73 feet.

A comment on the measurement of capital services is warranted. It may be difficult (costly) to increase the flow of capital services that are provided by a vessel of fixed size. Vessel capital is a lumpy input and fisherman cannot employ a fraction of its available service. The implication for modeling the harvest technology is that vessel capital services can be viewed as a weakly disposable or congested input. An increase in the capital services likely requires an increase in other inputs (labor and fuel) in order to maintain a given output level. The structure restriction of weak input disposability for x_3 is examined below.

3.1 Empirical methodology

The goal of the empirical analysis is to derive consistent unbiased estimates of Farrell output efficiency, $\delta(y,x) = 1 + \overrightarrow{D}(x,y|y)$, and to investigate the effects of environmental factors on harvesting performance. Environmental factors may include the skill level of the vessel captain and crew, stock abundance, quasi-fixed capital, vessel ownership and/or regulations used to control overfishing. Conditional on a given set of environmental factors, which we denote $z \in \Re^L_+$, vessel operators organize conventional inputs, labor, fuel and capital services and target output groups, shallow water groupers, deep water groupers, and non-reef fish species to best meet management objectives.

Following Simar and Wilson (2007), we assume that sample observations are independently and identically distributed random variables drawn from a common probability density function, and that the conditional distribution of Farrell output efficiency $\delta(y,x|z)$ operates through the mechanism;

$$\delta(y,x|z) = z\beta + \varepsilon, \tag{5}$$

where $\varepsilon \sim N(0, \sigma^2_\varepsilon)$. Equation (5) decomposes output inefficiency into a systematic component, $z\beta$, and a non-systematic term, ε. Hereafter, we refer to ε as the idiosyncratic component of output efficiency. By construction ε represents vessel-specific inefficiency which is unexplained by the conditioning component $z\beta$. A semi-parametric model is used to obtain consistent estimates of β and σ_ε and bias-corrected estimates of $\delta(y,x|z)$ for each vessel operation (see Simar and Wilson, 2007, for a complete description of the estimation procedure).

The semi-parametric model offers distinct advantages over standard one-step nonparametric methods. First, a double-bootstrap procedure corrects for downward bias inherent in finite sample non-parametric efficiency estimation.[12] A second advantage, which may be particularly important for predicting harvesting performance under new management, relates to the decomposition of total efficiency into its systematic and idiosyncratic compo-

[12] See Simar and Wilson (2000) for additional discussion of bias in non-parametric (data envelopment analysis) estimation. Walden (2006) applies a bootstrap bias correction in a non-parametric analysis U.S. mid-Atlantic sea scallop fishermen.

nents. Identifying environment factors which explain systematic inefficiency can refine *ex ante* predictions of harvesting performance under IFQs. For example, highly skilled vessel skippers will earn higher profit margins and are thus more likely to remain active under the proposed IFQ management program. Identifying a systematic relationship between skill (or a proxy for skill) and output efficiency refines predictions of harvesting performance, i.e., predictions of which vessel operations will remain active under new management can be conditioned on z. On the contrary, the causes of idiosyncratic inefficiency, ε, are unknown. Idiosyncratic inefficiency must be treated differently when constructing ex ante estimates of IFQ-regime harvesting performance. Section 4 below demonstrates the differential treatment of total inefficiency.

Lastly, researchers have proposed alternative methods for incorporating environmental factors into the analysis of production efficiency (see Coelli et al., 1998, pp. 166-172 for a review of these methods). The current approach is based on a coherent data generating process and has been shown to exhibit superior estimation performance in Monte Carlo experiments (Simar and Wilson, 2007).

3.1.1 Environmental factors and harvesting performance

A potentially important factor impacting the performance of commercial harvesting operations is the skill level of the vessel captain and crew (Squires and Kirkley, 1999). Our data contain the years of experience for the vessel captain which we use to proxy the skill of the labor employed by each vessel operation. Another factor which may cause inefficiency in the short run is the vessel configuration (e.g., vessel size, age, engine horsepower, crew berths). While non-optimal vessel configurations are likely to be replaced over time, constraints on capital investment and divestment may keep unproductive vessels active in the short run. Available proxies for the configuration of the vessel capital include vessel length, age, hull type (e.g., wood, fiberglass or steel) and engine horsepower.

Our data reports the region of each vessels' principle port. Regions range from the Florida Keys, to the northern waters off the coast of Franklin, Wakulla and Taylor counties in northwest Florida. Regional effects may capture differences in unobserved local stock abundance. Our data reports the main port from which each vessel fishes; we do not observe the actual location of fishing. Since vessels can easily move across regions and land fish at any port, it is questionable whether the region of port variable can proxy for differences in stock abundance. A second limitation is that a common regional effect cannot control for differences in abundance across multiple reef fish species. On the other hand, since policy makers are likely to be concerned about the distributional impacts of the IFQ program on local communities, inclusion of the regional variable can be informative.

Lastly, three different gear types were used in the grouper fishery in 1993; longline gear, vertical lines and fish traps (regulations eliminated fish trap gear in 2007). Many vessels specialize in a single gear type, although 30 boats in the sample report fishing with multiple gear types. To test whether differences in the gear used to harvest reef fish affects vessel performance, the share of each vessel's trips that used longline, vertical line, and fish trap gear are included as environmental factors.

4 Results

Following standard procedures, only minimal assumptions of closedness and convexity for the underlying harvest technology are imposed a priori. We allow the data to determine additional structural assumptions. The empirical model is estimated under three structural assumptions; (i) variable returns to scale with weak disposability for capital services, x_3, and strong disposability for fuel and labor, (ii) variable returns and strong disposability for all inputs, and (iii) constant returns with weak disposability for x_3.[13] The variable returns and weak capital disposability assumptions fit the data best. A Wilcoxon-Mann-Whitney test of free input disposability for vessel capital services is rejected at the 97.7% level of confidence. The structural restriction of constant returns to scale is rejected also at the

[13] An estimate of the feasible set $\widehat{T}$ under the maintained hypothesis of weak-capital (x_3) disposibility and variable returns to scale is,

$$\begin{aligned}\widehat{T} = \{(x,y):\ & y_m \leq \textstyle\sum_k \lambda_k y_{k,m}, && m = 1,2,3,\\ & x_n \geq \textstyle\sum_k \lambda_k x_{k,n}, && n = 1,2,\\ & \mu x_n = \textstyle\sum_k \lambda_k x_{k,n}, && n = 3,\\ & \textstyle\sum_k \lambda_k = 1,\ \lambda_k \geq 0,\ \forall k,\ 0 \leq \mu \leq 1\}\end{aligned}$$

	Model 1		Model 2	
Variable	Estimate	90% c.i.	Estimate	90% c.i.
Intercept	16.025	[8.400, 20.253]	19.108	[11.955, 20.552]
Exper.	-0.104	[-0.190, 0.015]	-0.111	[-0.191, -0.001]
Exper.^{2}	0.003	[.23e-4, 0.004]	0.003	[.64e-4, 0.004]
Length	-0.566	[-0.653, -0.223]	-0.644	[-0.669, -0.297]
Length^2	0.006	[0.002, 0.007]	0.007	[0.003, 0.007]
Shr.Vert	1.451	[-0.066, 1.626]	-	-
Shr.Trap	0.985	[-0.548, 1.517]	-	-
Region	0.015	[-0.152, 0.156]	-	-
σ_ε	2.271	[2.143, 2.696]	2.329	[2.246, 2.696]

Table 2: Parameter Estimates and Bootstrap Confidence Intervals `'Exper.' is years of experience for vessel captain; 'Length' is vessel length in feet; 'Shr.Vert' is catch share using vertical hook and line gear; 'Shr.Trap' is share of catch using trap gear; 'Region' is region of vessel's main port; There are 149 observations.`

97.7% confidence level. Unless noted, the results that follow assume variable returns to scale and weak disposability for x_3.

Table 2 reports parameter estimates and 90% double bootstrap confidence intervals for β and σ_ε. Results from two model specifications are reported.[14] Model 1 includes a constant term, skipper experience (Exper.) and vessel length (Length), both of which are entered qaudratically, gear type variables (Shr.Vert and Shr.Trap) and region (Region) of the vessel's main port. The base case includes vessels which take primarily longline gear trips.

Results indicate that output efficiency is impacted nonlinearly by captain experience and vessel length. Captains with roughly 20 years experience tend to attain the highest efficiency scores, whereas captains with less and more years experience operate farther from the frontier. Vessels that are roughly 46 feet in length tend to attain highest efficiency; shorter and longer boats do not perform as well. Model 1 find that gear types and region of main port do not have a statistically significant effect on harvesting efficiency, as the parameters associated with these variables have 90% confidence intervals that contain zero.

[14] Several alternative specifications which included cross effects were considered and rejected. Other environmental factors such as engine horse power and vessel hull construction (i.e., wood, fiberglass and steel) were found to have insignificant or trivial effects on output efficiency.

Model 2 of Table 2 reports results with gear type and region variables dropped. The results are almost unchanged indicating again that captains with roughly 20 years experience and vessels 46 feet in length attain the highest Farrell efficiency scores.

Based on the specification of model 2 in Table 2 the results indicate considerable inefficiency is present in the data. The sample mean value of $\delta(x, y|z)$ is 3.53 (the median is 2.56, and the standard deviation is 3.37). To more easily interpret these results we invert $\delta(x, y|z)$ to obtain estimates of the Shephard output distance function. The sample average value for $D_o(x, y)$ is 0.491 indicating that on average vessels harvested only 49.1% of the frontier harvest quantity. The extent of inefficiency indicated is significant but not unusual in the analysis of commercial fisheries. For instance, Weninger and Waters (2003) report that reef fish vessels in the northern Gulf of Mexico harvested 65%-70% of the frontier quantity of red snapper and other reef fish species, respectively. These authors calculate a directional distance function which expands output non-radially, and employ a single-step nonparametric model which is biased upward. Note that without the bootstrap bias correction, the sample average value for $D_o(x, y)$ among our sample of grouper fishermen increases to 0.569, which is similar to previous work.

The low efficiency indicated in the grouper data may be explained by the presence of part-time vessel operations (Table 1). Part-time fishermen take only a few trips each season and harvest small quantities of reef fish. These vessels may be considerably less productive than their full time counterparts which are operated by experienced, and likely more-skilled, captain and crew. The inefficiency found in the data does suggest a source of economic gain under IFQ management. In particular, redistributing the harvesting responsibilities to the efficient boats in the fleet will reduce the inputs per unit of harvested fish and thus reduce the cost of harvesting the allowable reef fish catch. Of the 990 commercially licensed vessels that reported reef fish landings in the 1993 National Marine Fisheries Service logbook data, 525 reported less than 5,000 pounds of total landings. Thus the number of part time vessels is large, as should be the gains from redistributing their catch share to full time operations.

Higher Farrell output efficiency will yield higher profit per unit of reef fish harvest. The results in Table 2 are thus suggestive of the types of vessel operations most likely to remain active under IFQ management. Note however, that this conclusion does not account for the idiosyncratic component of harvesting performance reflected in the error term ε. That is, there appears to be an important component of output efficiency which is not explained by environmental factors. The next section exploits the results in Table 2 to predict fleet size and overall harvesting performance expected under IFQ management.

5 Fleet structure and economic gains under IFQ management

We will suppose that the 1993 grouper fishery is managed with IFQs for shallow and deep water groupers, and that the commercial fleet is in equilibrium as described by condition C1, and C2 in Section 2. To simulate conditions in the fishery in 1993 we assume that the total harvest permits issued are equal to the quantity of reef fish harvested by the commercial fleet. Log book records indicate that 13.092 million pounds of shallow water groupers and 0.622 million pounds of deep water groupers, for a total of 13.754 million pounds of reef fish, were harvested in the eastern region in 1993.[15] Total allowable harvests are set at $Y_1 = 13.092$ million pounds and $Y_2 = .622$ million pounds. The equilibrium fleet structure is calculated following similar steps as in Weninger and Waters (2003). The analysis will then be repeated to simulate more recent allowable catch targets which are $Y_1 = 9.8$ million pounds and $Y_2 = 1.6$ million pounds.

We begin with a prediction of activity levels for representative vessel lengths. As noted, under IFQs active vessels will adjust inputs and outputs to exploit available economies of scale and scope in production. Skippers inform us that gear modifications are required to harvest non-reef fish species, y_3. These modifications represent a superadditive fixed cost for a vessel operation. We find no evidence to suggest cost complementarity between reef and non reef fish species. This suggests there are diseconomies of scope associated with the harvest of non-reef fish species. Correspondingly, the output harvested by an IFQ-regime vessel is predicted to consist of positive quantities of reef fish, y_1 and y_2, and zero quantity of non-reef fish species, $y_3 = 0$. Predicting the precise mix of y_1 and y_2 for active vessels will

[15] The total catch of non-reef fish species was 0.651 million pounds in 1993.

not be attempted.[16] Rather, we assume that representative vessels harvest a mix of reef fish equal to the total allowable harvest quantities during the 1993 season, i.e., $y_2/y_1 = Y_2/Y_1$.

The results of section 4 find that the reef fish harvest technology exhibits variable returns to scale. A large number of boats in the sample (73 of 149 or 49%) are found to operate in a region of increasing returns. Consolidating the reef fish catch onto fewer boat will reduce variable harvesting costs for the fleet. Furthermore, indications are the 1993 fleet is (was) large compared to the fleet that will remain active under the IFQ program (see additional results below). Reef fish vessels incur non-trivial annual fixed costs in the form of vessel and gear maintenance costs, docking fees, license fees, and accounting and legal fees. This implies that a reduction in the fleet size under the IFQ regime will reduce annual fixed costs incurred by the commercial fleet.

We identify the optimal scale of operation using the following approach. Our results from section 4 find that 30 of the 149 vessels in our sample attain a Farrell efficiency score of unity; these vessels operate on the boundary of the variable returns to scale output set, $\widehat{T}$. The observed inputs for these boats provide the benchmark input bundle for our representative vessels. Holding the input bundle fixed, we estimate the directional distance function for output $\widehat{y} = (1, Y_2/Y_1, 0)$ using directional vector $g_y = \widehat{y}$. We then calculate the frontier output, $y^f = \widehat{y}(1 + \overrightarrow{D}(x, y|\widehat{y}))$. The result y^f is the frontier output conditional on the assumed output mix and the input bundle used by efficient sample boats. The estimated activity (x, y^f) is thus fully efficient, in the sense that it attains Farrell technical efficiency $\delta(x, y^f) = 1$.

Condition C2 in Section 2 states that the IFQ regime fleet will be comprised of the most efficient vessels in the fleet. The switch to IFQ management does not imply that all active vessel will operate on the boundary of the feasible technology, i.e., some level of harvesting inefficiency is expected to persist under the new management program. The frontier output y^f must be adjusted to account for harvesting inefficiency under the IFQ program. The following steps are used to make this adjustment.

The semi-parametric model finds that systematic output efficiency is highest on ves-

[16] See Squires and Kirkley (1995, 1996) for additional discussion of equilibrium fleet structure in multi-species fisheries under rights-based management.

sels 46 feet long, operated by skippers with 20 years experience, but that the idiosyncratic component of the output efficiency, ε, represents a significant component of measured performance. Vessel operations with the lowest value of ε are expected to remain active. We can rank the idiosyncratic efficiency from lowest to highest to calculate an expected level of output efficiency attained by the active IFQ-regime fleet. The calculations are as follows.

We first calculate the q'th quantile value ε_q. Recall that ε is a left truncated normally distributed random variable with mean zero and variance σ_ε^2. For conditioning variables z the estimate of ε_q is obtained as,

$$\varepsilon_q = \widehat{\sigma}_\varepsilon \Phi^{-1}\left(q + \Phi\left((1 - z\widehat{\beta})/\widehat{\sigma}_\varepsilon\right)\right),$$

where *hats* denote estimated parameter values, and $\Phi(.)$ is the standard normal cumulative distribution function. We then calculate the expected value of ε conditional on ε being below the q'th quantile value ε_q;

$$\overline{\varepsilon}_q = E[\varepsilon | \varepsilon < \varepsilon_q] = \frac{\phi(\varepsilon_L) - \phi(\varepsilon_U)}{\Phi(\varepsilon_U) - \Phi(\varepsilon_L)},$$

where $\varepsilon_L = (1 - z\widehat{\beta})/\widehat{\sigma}_\varepsilon$, $\varepsilon_U = \varepsilon_q/\widehat{\sigma}_\varepsilon$, and $\phi(.)$ is the standard normal density function. The expectation of Farrell output efficiency, conditional on idiosyncratic efficiency falling below the q'th quantile value is then obtained as $\overline{\delta}_q = z\widehat{\beta} + \overline{\varepsilon}_q$. Finally, predicted harvest conditional on $\overline{\delta}_q$ is then obtained as $y = y^f/\overline{\delta}_q$.

Table 3 reports estimates of vessel activity levels, harvesting costs, fleet size, harvest permit prices and fishery rent predicted in the IFQ-managed grouper fishery. For comparison, three vessel lengths, and two levels of expected idiosyncratic harvesting performance are considered. Results in the top half of the table assume that the marginal or least efficient vessel in the IFQ-regime fleet attains the 20'th quantile value of idiosyncratic output efficiency (estimated from our sample vessels). Results in the table's lower half assume the marginal boat attains the 10'th quantile value for ε. All results assume that the vessel captain has 20 years experience.

Fixed cost estimates are obtained from the cost survey data and consist primarily of hull

Length feet	$\overline{\delta}_q$	y_1 '000 lbs.	y_2 '000 lbs.	FC '000 $	VC '000 $	RAC $	r_1 $	r_2 $	Boats	Rent $ Mill.
$\overline{\delta}_q$= 0.20										
35	1.979	20.687	0.983	2.237	41.995	2.014	-0.102	-0.165	633	-1.443
45	1.747	51.508	2.447	2.874	82.027	1.574	0.365	0.302	254	4.971
55	1.867	56.063	2.664	3.511	103.098	1.815	0.123	0.060	234	1.654
$\overline{\delta}_q$= 0.10										
35	1.552	26.388	1.254	2.237	41.995	1.600	0.339	0.276	496	4.605
45	1.399	64.321	3.056	2.874	82.027	1.260	0.679	0.616	204	9.269
55	1.477	70.886	3.368	3.511	103.098	1.436	0.503	0.440	185	6.860

Table 3: Predicted vessel activity and fleet structure under IFQ management. `FC is fixed cost, VC is variable cost, RAC is ray average cost. All values are US 1993 dollars.`

and gear maintenance costs, docking, licensing, administrative, and legal fees, and insurance expenses. Ray average cost (RAC) is calculated as variable plus fixed cost divided by total catch, where units are normalized to $y_1 = 1$, and $y_2 = Y_2/Y_1$ (Baumol, et al. 1982).

Consider the results for $q = 0.20$. Consistent with the results in section 4, RAC is lowest for 45 foot boats. A 45 foot boat operating at efficient scale of production could earn a harvest permit rent of \$0.365, and \$0.302 per pound for shallow and deep water groupers, respectively. The per pound rent earned on a 35 foot boats and 55 foot boats is less. In fact, 35 foot vessels attain expected Farrell output efficiency $\overline{\delta}_{20} = 1.979$ and do not cover total costs at 1993 reef fish prices, i.e., the per unit rent which includes the harvest permit rental is negative for 35 foot boats. With harvest permit lease prices in the range of $r_1 = \$0.365$ and $r_2 = \$0.302$, 35 foot and 55 foot operations are unprofitable when quota ownership opportunity costs are taken into account. The model predicts that these smaller and larger boats will not remain active under IFQ management.

The last column in Table 3 reports an estimate of the fishery resource rent generated under the various fleet structures. If the IFQ-regime fleet is made up entirely of 45 foot vessels, 254 such vessels would be required to harvest the 13.092 millions pounds taken from the fishery in 1993. A fleet consisting of 254, 45 foot boats, earns total revenues less total costs equal to \$4.97 million.

The results for the case where the marginal boat attains the q =10'th quantile level of Farrell output efficiency change in expected ways. Harvest per vessel is increased due to increased output efficiency. Vessel costs are unchanged, which means that RAC declines. Harvest permits prices increase as does total fishery resource rent. Notice that when $\overline{\delta}_{10}$ is assumed, RAC on 35 foot boats is below 1993 prices. Of course, rent per unit of harvest remains below the level attained on 45 foot and on 55 foot boats. Again the model predicts that these smaller and larger boats will be inactive under the IFQ program.

The predicted fleet sizes in Table 3 illustrate the extent of fleet downsizing that is expected under IFQs. While a precise measure of the size of the active fleet in the grouper fishery is difficult to conceive due to the part-time nature of many vessels and vessel participation in multiple fisheries, the number of vessels that reported landings in 1993 provides a qualitative indication of expected downsizing.[17] National Marine Fisheries Service log book data indicate that 990 vessels harvested positive quantities of reef fish in the eastern Gulf region in 1993. Many of these boats landed only small quantities of grouper and other reef fish found in the eastern Gulf region; 465 reported harvests in excess of 5,000 pounds, 331 reported harvests in excess of 10,000 pounds, and 229 reported harvests in excess of 20,000 pounds. The results in Table 3 suggest that the IFQ-regime fleet size would range between 200-250 vessels. Notice that the total catch per vessel in (Table 3) is in the range of 54,000 pounds for a 45 foot boat. Further examination finds that the average catch for the 149 sample boats is a mere 29,020 thousand pounds (Table 1). Of the 149 sample boats, seventy five percent harvested less than 41,000 total pounds (including non-reef fish species). Thus the raw data appear to support the predictions for equilibrium fleet size reported in Table 3.

We next compare the actual fishery rent in 1993 with the rent that is predicted under the IFQ-regime fleet. The rent difference is an economic benefit of management reform. To make this calculation we require an estimate of the costs incurred by 1993 reef fish boats. As mentioned above, one problem in estimating actual total cost is that sample vessels participate part time and in other fisheries. It is not clear how much of the annual fixed costs should be attributed to grouper fishing. We avoid this complication by focussing on variable costs only. It should be emphasized that because fixed cost savings are not

[17] Commercial fishing vessels operating in the eastern Gulf of Mexico reef fish (grouper) fishery harvest multiple reef and non reef fish species, using multiple gear types throughout each year. A complete accounting of annual vessel-level harvesting activities is not available.

considered the results that follow represent a lower bound estimate of the total cost savings expected under an IFQ management program.

An estimate of the actual reef fish variable costs in 1993 is obtained by first removing sample vessels that harvested more than a 10% share of non-reef fish species (this removed 5 boats). We then multiply the variable harvesting costs for the remaining sample by their respective share of the total sample reef fish harvest. Ray average variable costs are then calculated for each sample boat and an estimate of fleet wide ray average variable costs is obtained as a weighted average, with weights set as the vessel's share of the total sample catch.

This calculation yields an estimate of actual RAC in 1993 of \$1.73, and an estimate of total fleet variable cost (reef fish only) equal to \$23.77 million. Vessel revenues in 1993 were \$26.55 million. Ray average variable costs under the predicted IFQ-regime fleet structure range between \$1.22 and \$1.52 for 45 foot vessels, depending on the level of output efficiency assumed. Variable harvest cost saving are thus estimated to range between \$2.92 and \$7.07 million dollars.

Lastly, we repeat the above calculations to examine fleet structure and economic rent under the total allowable catch targets of $Y_1 = 9.8$ million pounds of shallow water groupers and $Y_2 = 1.6$ million pounds for deep water groupers. We assume that the IFQ-regime fleet is comprised of 45 foot vessels with the marginal vessel attaining the q =10'th quantile level of idiosyncratic efficiency. Under these smaller total allowable catch levels, the model predicts a fleet size of 153 boats, and resource rents in the fishery equal to \$7.64 million.

5.1 Implications for grouper management reform

The results suggest significant cost savings are available under an IFQ management program in the Gulf of Mexico grouper fishery. Several factors should be considered when assessing the robustness of these results. This section presents a necessarily informal discussion of two of these factors. First, the cost savings estimates are derived from a sample of vessels operating in 1993 and are thus conditional on the bioeconomic and regulatory conditions that prevailed in the fishery at that time. Fleet structure, regulations and stock levels change over time which suggests caution when extrapolating the cost savings estimates beyond the study period. Second, the analysis above assumes the IFQ harvest fleet is in equilibrium. The cost savings that are realized during the transition to this equilibrium must be less than under the new equilibrium, and delays in the transition to the new equilibrium will reduce benefits from managmeent reform.

5.1.1 Extrapolation outside the sample data period.

The original Reef Fish Fishery Management Plan was implemented in November 1984. The plan introduced regulations designed to rebuild declining reef fish stocks and included prohibitions on certain gear types within an inshore stressed area, a minimum size limit of 13 inches total length for red snapper (an important target species in the northern region of the Gulf reef fish fishery) and data reporting requirements.

More recent concerns of overfishing for grouper species have resulted in a host of additional regulations. Secretarial Amendment 1 to the Reef Fish Fishery Management Plan (July 15, 2004) established a 5.31 million pound commercial quota for red grouper and reduced aggregate quotas for shallow and deep water groupers. The shallow water grouper quota was lowered from 9.8 to 8.80 million pounds. The red grouper quota was established at 5.31 million pounds and the deep water grouper quota was reduced from 1.6 million to 1.02 million pounds. Under the aggregate quota regulations, the fishery is closed as soon as the quota is met (closure of the shallow water grouper fishery occurs as soon as either the red grouper or the aggregate shallow water grouper quota is met).

To slow the ensuing race for fish under aggregate quota regulations, per trip catch limits of 6,000 pounds of grouper species were implemented in March 2005. Trip limits were however not sufficiently restrictive and seasonal closures for both shallow and deep water groupers have been required since 2005. Grouper fisheries are also closed from February 15 through March 15 to protection spawning aggregations. Finally, recently completed stock assessments for gag grouper raise new concerns of overfishing. An aggregate gag grouper quota and further tightening of trip limits are now being considered by regulators.

The top panel of Figure 1 reports the number of commercially licensed vessels that

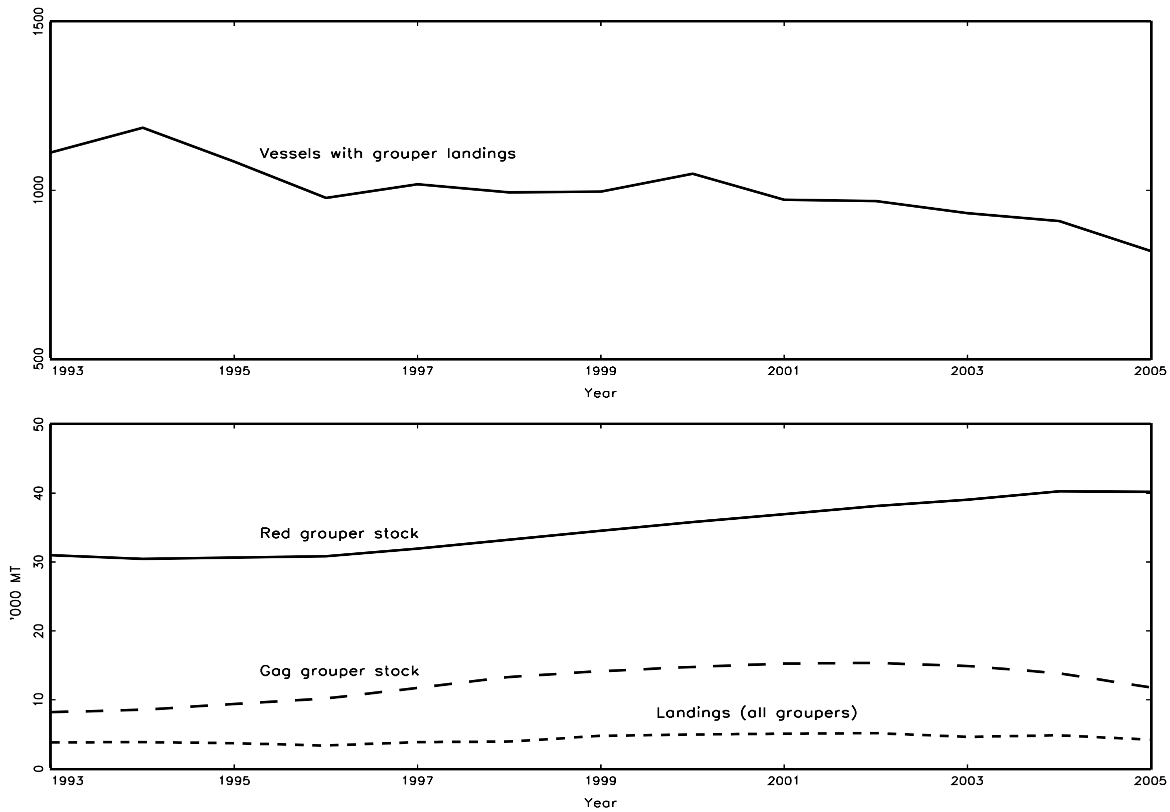

Figure 1: Fleet Size, Stock Abundance and Grouper Landings, 1993-2005.

registered positive grouper landings during 1993-2005.[18] The data show that participating vessels have declined steadily from 923 in 1993 to 671 in 2005. While the grouper fishery has seen a 27.3% decline in the number of active vessels, the 2005 fleet remains considerably larger than is predicted under the IFQ equilibrium (200-250 boats).

The bottom panel in the Figure reports estimates of red and gag stock abundance over the same period. Stock assessments for other grouper species are not available. Estimates indicate that red grouper stock abundance has increased since 1993 whereas gag grouper abundance increased during 1995 and 2001 and declined thereafter. The table reports both red and gag grouper abundance that is slightly larger in 2005 than in 1993. The bottom

[18] Data in Figure 1 are from the Gulf of Mexico Fishery Management Council (2007). Fleet size is calculated as the number of vessels with positive landings of any grouper species, and thus differs from vessel numbers reported above.

panel also reports the aggregate commercial grouper landings during the 1993-2005 period.

Absent from the Figure is the fleet-wide average harvesting costs during the period. One might speculate that the decline in the grouper fleet was due in part to the exit of relatively inefficient vessel operations. If this is the case, the cost savings from a switch to IFQ management in the current day fishery could be less than suggested by the analysis of our 1993 data. The bottom panel reveals that total landings of grouper species have remained fairly flat since 1993 (note that landings of other reef fish species are not included). Hence, the annual catch per boat has increased by roughly 49% between 1993 and 2005. If a larger share of the annual reef fish harvest was landed by the remaining, relatively efficient, vessels during 1993-2005, the cost savings measured in 1993 may overstate gains from management reform.

On the other hand, it is very likely that recently implemented per trip catch limits and seasonal closures have resulted in further increases in unit harvesting costs. Taking these recent regulatory developments into account suggests that cost savings estimates based on the less restrictive regulations in 1993 likely understate the benefits from management reform in the current day fishery.

Finally, it should be emphasized that because the analysis of this paper relies on currently available data, adjustments in marketing practices, capital configuration, process innovations, or adjustments in total catch quotas, which may also occur in response to IFQ operating rules, are not considered in the estimation of benefits. The form and extent of these adjustment are difficult to predict ex ante. However, such adjustments are expected to occur only if they are deemed privately profitable from the viewpoint of industry. To the extent that IFQs correct market failures in fisheries, privately optimal investments should increase economic rents generated in the grouper fishery. Correspondingly, the estimate of economic benefits reported in this paper represent a lower bound to the full benefits that are available in the fishery in the longer term.

5.1.2 Delays in fleet restructuring

Indications are that significant fleet downsizing must occur before the full efficiency gains from IFQ management are realized. Work by Weninger and Just (1997), and more recently

Vestergaard et al. (2005) provide theoretical analyses of fleet adjustment in the transition from an open access to an IFQ-managed fishery. These studies provide little practical guidance to predict actual patterns of fleet adjustment, or the speed with which adjustments might take place.

Fleet restructuring in fisheries that have switched to IFQ management may provide some insights. Researchers find that following the implementation of IFQs in New Zealand fisheries, the rate of vessel exit was initially rapid for some vessel classes but slow and steady for others. Studies also reveal that small-scale fishing operations were more likely to exit under the new Quota Management System (Stewart et al. 2006; Stewart and Walshe, forthcoming). Data reported in Turner and Weninger (2006) indicate that vessel capital was shed rapidly during the first year of the individual fishing quota program in the U.S. Mid-Atlantic clam fishery. The restructuring process followed a more gradual process in subsequent years. In sum, past experiences with IFQ management in fisheries suggest that fleet restructuring could be prolonged.

In sum, the rate of restructuring and the date at which the IFQ-equilibrium will emerge in the grouper fishery remains a complex issue that is beyond the scope of this paper.

6 Conclusion

This paper constructs an ex ante estimate of the economic benefits of implementing a rights-based (IFQ) fisheries management program in the eastern Gulf of Mexico reef fish fishery. A semi parametric model is used to analyze harvesting inefficiency under the current controlled access management system. The empirical model corrects for bias inherent in single step non-parametric efficiency analysis and provides a framework to consistently identify the impacts of environmental factors on harvesting performance. The paper shows how identification of these factors can refine estimates of the economic benefits expected under rights-based management, and may guide policy makers concerned with the transitional impacts of management reform.

Results find significant harvesting inefficiency due to operation at non-optimal scale of operation and technical inefficiency persist under the controlled access management program in the eastern Gulf reef fish fishery. Findings suggest further that moderately sized vessels operated by mid-career captains attain the highest level of harvesting efficiency, and thus are expected to dominate the IFQ-regime fleet. Scale economies are predicted under IFQs as the reef fish allowable catch is consolidated onto fewer boats. Pure technical efficiency gains are also expected as the bulk of the harvesting responsibility is carried out by the most productive vessel operations in the fleet.

Calculations reveal that the equilibrium IFQ-regime fleet would be reduced considerably from current levels to roughly 200-250 vessels. The results suggest that the total reef fish catch in 1993, if harvested by a smaller more productive IFQ-regime fleet, could be harvested at cost saving in the range of $2.92-$7.07 million (12-30% below actual costs incurred). Additional fixed cost savings due to fleet downsizing push the cost saving estimate even higher.

Designing and implementing an IFQ management program presents a serious challenge for regulators and industry. Delays in the transition to the rationalized fleet could take time, and exiting boats could relocate to other fisheries causing further management problems. On the other hand, continuing with the current system of cost-increasing input controls does not hold much promise. Very recently, regulators have proposed additional restrictions on commercial harvesting activities including total catch limits for gag grouper and a further tightening of per trip grouper catch limits. These restrictions may reduce reef fish mortality but can only cause further increases in harvesting costs. An IFQ program may present an attractive alternative for managers and industry.

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