Fisheries Research 196 (2017) 106–116

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Research paper

Rights-based management for recreational for-hire fisheries: Evidence from a policy trial

Joshua K. Abbott[a,*], Daniel Willard[b]

[a] School of Sustainability, Arizona State University, PO Box 875502, Tempe, AZ 85287, United States
[b] Environmental Defense Fund, 301 Congress Avenue, Suite 1300, Austin, TX 78701, United States

ARTICLE INFO

Handled by Prof. George A. Rose

Keywords:
Catch shares
For-hire sector
Recreational fisheries
Rights-based management
Sportfishing

ABSTRACT

Most for-hire recreational fisheries are managed using season, bag and size limits. Yet these approaches do little to control fishing effort or mortality and may dissipate value to anglers and vessel owners. Rights-based management approaches could theoretically address these shortcomings but are untested in the for-hire recreational context. We address this knowledge gap by examining the outcome of a two-year policy "experiment" in the U.S. Gulf of Mexico – a system plagued by shrinking seasons and tighter bag limits. Participating for-hire vessels in the Gulf Headboat Collaborative received individual allocations of red snapper (*Lutjanus campechanus*) and gag grouper (*Mycteroperca microlepis*) that they were free to fish outside of the usual seasons in exchange for enhanced accountability. We find that participants smoothed their offerings of red snapper and gag trips across the year, increasing anglers' access to these species. Regulatory discards of the allocated species declined as well. Vessel revenues and net revenues increased respectably despite a relatively unchanged number of trips after the policy change. Revenue increases were driven by increased anglers per trip in offseason periods and by shifting customers to longer, higher value trips through the promise of catching desirable species outside of the restrictive federal season. Surveys of vessel owners confirm the overall success of the policy trial and corroborate the quantitative analysis of the mechanisms underlying its economic benefits. We conclude with a discussion of the usefulness and limitations of this policy trial for predicting the long-run outcomes of permanent rights-based management policies for the for-hire sector.

1. Introduction

The recreational contribution to fish mortality is significant and growing (Coleman et al., 2004; Ihde et al., 2011) with approximately 11 million marine anglers taking 68 million fishing trips in the U.S. annually (National Marine Fisheries Service, 2016). These trips contribute significant economic value and impacts for coastal economies (Lovell et al., 2013). Recreational fisheries have grown in importance in the European Union (Pawson et al., 2008), Australia and New Zealand (Borch, 2010; Kearney, 2001), and other developed nations (World Bank, 2012), and are increasingly important in developing nations as well (Pitcher and Hollingworth, 2002).

Despite their importance, marine recreational fisheries have seen little policy innovation. Most fisheries have long operated under a regime of license fees and season, size and retention constraints. While perhaps sufficient for stocks faced with limited angler demand, these approaches have done little to curb fishing mortality (Cox et al., 2002; Woodward and Griffin, 2003; Lewin et al., 2006) due to their inability to contain overall effort or adequately adjust to anglers' adaptive behaviour (Fenichel et al., 2013). As a result, recreational fisheries for many popular species are following a well-trod path observed in commercial fisheries governed by regulated open access institutions (Reimer and Wilen, 2013): an escalating pattern of shorter seasons and increasingly tight regulation (Wilen, 2006). This management may dissipate angler welfare in several ways, including excessive participation (Anderson, 1993; Fenichel and Abbott, 2014; Stoeven, 2014), congestion during brief fishing seasons (Timmins and Murdock, 2007), and misallocation of scarce landings to anglers with low valuations through inflexible bag limits (Abbott and Wilen, 2009) and seasonal openings (Holzer and McConnell, 2014; Abbott, 2015).

While anglers often access marine species by fishing from piers, the shore, or using their own vessels, many others rely upon the services of the for-hire sector (e.g., charter, headboat, or party boat vessels).[1] Regulation of the for-hire sector has closely mirrored the management

* Corresponding author.
E-mail address: Joshua.k.abbott@asu.edu (J.K. Abbott).

[1] 22% of US recreational landings are estimated to come from the for-hire sector (Figueira and Coleman, 2010). This share increases substantially for offshore species (e.g., tunas and billfish) that are out of reach for small private vessels.

http://dx.doi.org/10.1016/j.fishres.2017.08.014
Received 13 January 2017; Received in revised form 8 June 2017; Accepted 16 August 2017

of private anglers, often being subject to the same bag and size limits and seasonal closures. For-hire recreational fisheries are therefore prone to the same symptoms of regulated open access management as private recreational fisheries − albeit, with the added symptom of dissipated industry profits (Abbott and Wilen, 2009). Theoretical work has outlined how rights-based management (RBM) approaches, such as individual transferable quotas (ITQs), could be adapted to for-hire fisheries to enhance accountability for fishing mortality, provide operators the flexibility to offer year-round trips customized for their customers, and enhance consumer and producer surplus (Abbott and Wilen, 2009; Abbott et al., 2009; Leal and Maharaj, 2009). Rights-based approaches in commercial fisheries have enhanced economic efficiency and reduced overcapacity, while helping align the interests of fishermen with resource sustainability (e.g., Arnason, 2012; Grafton et al., 2006). The for-hire sector often shares features with the commercial sector that suggest it may be amenable to RBM. Like commercial fishermen, for-hire operators are profit-seeking and rely upon fish as an input to a marketed product (a service); they often hail from a relatively small and well-defined set of ports − fostering economies of scale in enforcement; and permit registries for-hire vessels can be used to define exclusion rights, while catch histories (when present) can facilitate initial allocations of these rights.

The theoretical promise of RBM has not, to the authors' knowledge, been actualized in any real-world for-hire fishery. This paper fills this void by reporting the results of a unique policy trial in the U.S. Gulf of Mexico (GOM), the Gulf Headboat Collaborative (GHC). For-hire vessels in the GHC operated under a two-year experimental pilot program of RBM for red snapper (*Lutjanus campechanus*) and gag grouper (*Mycteroperca microlepis*). This unique collaboration between the fishing industry, government, academia, and the environmental NGO community provides a first-of-its-kind examination of the performance of RBM approaches in for-hire recreational fisheries, providing useful insights for the expansion of these approaches to similar fisheries around the world.

1.1. Case study

The lack of innovation in recreational fisheries management is illustrated in the U.S Gulf of Mexico. This is a multispecies fishery with large for-hire and private recreational components sharing fish populations with a commercial sector. Reef fish, such as snapper and grouper species (along with coastal pelagics, tunas, and sharks), are popular offshore target species in the region.[2] Three of these − red snapper, gray triggerfish, and greater amberjack − are overfished and managed under rebuilding plans, while gag grouper was overfished until 2014 (NOAA Fisheries, 2014). For several reef fish species recreational fishing mortality exceeds commercial fishing mortality (NOAA Fisheries Southeast Regional Office, 2016). These large recreational harvests are fostered by significant allocations to the recreational sector, and yet persistent recreational overharvests are commonplace (NOAA Fisheries Southeast Regional Office, 2017). Accordingly, recreational seasons for popular species such as red snapper, gag grouper, and others are now closed for much of the year,[3] fostering distrust of management and increasing allocation tensions with commercial sector vessels fishing for red snapper and groupers year-round under rights-based policies (Abbott, 2015; Doerpinghaus et al., 2014).

The for-hire industry in the GOM has been particularly harmed by this state of affairs. For-hire vessels are the primary means for anglers without access to a private vessel to fish offshore. The GOM for-hire sector includes over 1300 vessels distributed across five states with permits to fish for reef fish species in federal waters. The sector includes a large charter boat component and approximately 70 headboats (or party boats) comprised of relatively large vessels that mostly charge per customer or "head" (Gulf of Mexico Fishery Management Council, 2016b). Shrinking seasons and bag limits, a reef fish for-hire permit moratorium, relatively lax regulations in state waters off-limits to federally permitted for-hire vessels, and expanding private recreational fishing effort have all contributed to a nearly 20% attrition of for-hire fishing permits (Gulf of Mexico Fishery Management Council, 2014). While it is common for anglers on for-hire reef fish trips to catch a varied "bag" of species, and a number of fisheries remain open much of the year, many vessel owners cite the inability to land popular or even iconic (e.g., red snapper) species outside of increasingly short seasons as a severe constraint on their business.

In this atmosphere, an affiliation of headboat operators in the GOM developed a pilot project to test an alternative approach. In partnership with Environmental Defense Fund, these operators organized as the Gulf Headboat Collaborative (GHC) and applied to NOAA Fisheries for an exempted fishing permit (EFP) to test a RBM approach.[4] This EFP authorized a unique experiment in a fundamentally different form of management, exempting participating vessels from federal recreational season closures and allowing potential year-round fishing subject to quota availability and enhanced reporting and monitoring requirements.

GHC's EFP application was endorsed by the Gulf of Mexico Fishery Management Council in April 2012 and approved by NOAA Fisheries in August 2013. The two-year pilot began in January 2014 and concluded in December 2015. Membership was voluntary and organized through contracting among participants. The GHC began with 17 vessels owned by 13 businesses in 2014, expanding to 19 vessels and 15 businesses in 2015. Vessels were 47–78′ in length, accommodating 20–80 passengers per trip. The GHC received annual allocations of red snapper and gag in proportion to participating vessels' collective 2011 landings of these species (National Marine Fisheries Service Southeast Regional Office, 2015), totalling 5% and 3% of total recreational catch limits for the two EFP species.

While the EFP yields insights for a range of for-hire fisheries, we limit direct inferences to the GOM headboat sector. Headboats are unique for having the landings histories required to support a vessel-based allocation process,[5] which has lead policymakers to propose separate RBM plans for the headboat (Gulf of Mexico Fishery Management Council, 2016b) and charter fleets (Gulf of Mexico Fishery Management Council, 2016a). Participation in the GHC was voluntary, but membership was geographically representative, with vessels distributed across Alabama, Florida and Texas.[6] The GHC also contains the range of firm sizes and economic contexts in the GOM headboat fleet − with some multi-vessel operators operating in tourist hotspots and single-vessel companies based in more remote ports. Altogether, our sample comprises approximately 25% of federally-permitted headboats in the GOM.

Regulators allocated quota and enforced accountability at a collective level, but the common pool of red snapper and gag quota was internally allocated to individual GHC vessels. The GHC was not bound to

[2] The GOM also has a large recreational fishery in state waters for spotted sea trout, red drum, and other species, but our focus is the offshore marine recreational fishery under federal management. Across all GOM recreational fisheries an average of 3 million anglers took 23 million fishing trips annually in the GOM from 2005 to 2014 (National Marine Fisheries Service, 2016).

[3] The recreational season for red snapper reached a low of nine days in 2014 (Gulf of Mexico Fishery Management Council, 2014) despite recovering stocks and larger annual catch limits over the years.

[4] An EFP is a temporary permit issued to individuals for the purposes of conducting research or other fishing activities for species under federal regulation (50 C.F.R. § 600.745(b)(1)).

[5] Unlike headboats, GOM charter boats are not required to report vessel-level landings histories.

[6] In 2015 there were 4 (5) GHC vessels in NW (SW) Florida, 5 vessels in Alabama, and 5 in Texas. These proportions are similar to industry-wide proportions (Gulf of Mexico Fishery Management Council, 2016b), albeit with a slight overrepresentation of Alabama vessels and the absence of any vessels from Louisiana/Mississippi, which together reflect ~10% of the headboat fleet.

any particular initial allocation rule, but in practice members used vessel catch histories to derive mutually agreeable allocations, recognizing members' different scales and types of fishing operations. Importantly, quota was made transferable between GHC participants, but transfers to nonparticipants were prohibited. In practice, the GHC operated as a for-hire fishing cooperative (Deacon, 2012). Members signed a contract that bound them to an operations agreement. A manager, one of the vessel owners, handled day-to-day operations, and oversight was provided by a board of fellow GHC members. Participating vessels were held to a higher standard of monitoring and enforcement than the rest of the headboat sector. Each was required to use vessel monitoring systems (VMS) with a tablet interface, to hail in/out to law enforcement before and after each fishing trip, to submit electronic logbooks on the same day as each fishing trip, and abide by a more stringent regimen of dockside intercepts from enforcement authorities. These additional requirements were needed to ensure a sufficiently accurate and timely record of catch to inform quota tracking at the individual vessel level and thereby avoid overages. As a condition of the EFP, GHC members were also required to participate in scientific research and deliver to NOAA Fisheries a report on the socioeconomic impacts of the program. To that end GHC members cooperated with academic researchers in a research program intended to evaluate the pilot program's impacts. This paper utilizes the primary and secondary data sources gathered as part of this research.

2. Material and methods

2.1. Data

Our primary data are the 2003–2015 catch records from the Southeast Region Headboat Survey (SRHS) administered by the NOAA Southeast Fisheries Science Center Beaufort Laboratory. The SRHS is used for the purpose of effort and catch accounting for the headboat sector and provides trip-level observations on species-specific catch and discards, trip duration, and number of customers. The data were provided in unmodified form for all vessels covered by the SRHS that were owned by GHC participants in 2014–2015 for the entire period for which permit data indicated that the vessel was under the same ownership. We were also provided aggregated SRHS data at the scale of weeks and 5 regions for non-GHC vessels.

The second major data source is the responses to surveys of GHC headboat owners. The surveys were administered through a combination of in-person interviews and mail in January-March 2014, at the very beginning of the EFP, and were repeated in the spring of 2015 and 2016 using the Qualtrics online survey platform. The surveys were administered to establish a pre-EFP baseline and within-EFP economic datasets (e.g., trip offerings, pricing, variable and fixed costs) as well as more open-ended questions about how aspects of the business had changed. We combine these data with the SRHS to provide estimates of revenues and net revenues for GHC vessels.

Understanding the limits of our data and the assumptions behind our calculations is important for the proper interpretation of our results. Our survey data contain data on the pricing of the overwhelming majority of trips offered on a "per head" basis as well as some data for trips in which parties charter the entire vessel. However, temporal inconsistencies in the recording of SRHS data prevent us from reliably matching trips after 2013 to either category. Therefore we treat all trips by GHC vessels as headboat trips. While this likely underestimates revenues in any given year (charter trips typically yield higher revenues), it does provide a consistent basis for evaluating *changes* in revenues.

Another ubiquitous challenge relates to the resolution and reliability of the cost data. There is little experience among GOM headboats of being surveyed about operating costs (cf. Savolainen et al., 2012), and we found that the reliability of cost accounting varied widely across operations. Therefore data were elicited at a level of detail that was feasible for all participants; in each year we requested average input use (e.g., fuel, bait, and ice) along with average input prices for each trip type and information on crew and captain compensation. These data reliably establish the cost share of variable inputs for each trip type; however, we expect they are measured with too much error to identify variations in input usage and costs across years. Therefore, we do not attempt to perform an analysis of EFP-driven cost savings for particular trip types. Given the high quality of the fuel cost data,[7] the large share of fuel costs (13% of revenues on average), and since fuel savings are the only pathway for EFP-driven cost reductions mentioned by headboat owners in the survey, we focus exclusively on this cost category in the subsequent analysis. Therefore, 'net revenues' are defined below as revenues net of fuel costs.

Our comparisons of revenues are limited to the 17 2014 GHC vessels so that inter-annual comparisons are across a stable cohort. Revenue estimates are formed by matching trips from the SRHS to pricing and fuel cost data from the annual headboat owner survey. Over 99% of trips were matched. Due to the lack of pre-2014 price/cost data and in order to isolate changes in revenues driven by changes in demand or trip operations vs. exogenous price increases, all revenues are calculated using fixed 2014 values for trip prices, fuel prices, and fuel usage for a given vessel and trip duration. Therefore, variation in calculated revenues across years occurs due to changes in trip offerings and the assortment of customers across these trips, not changes in pricing over time. The one exception is for cases where companies reported charging a price premium specifically for trips retaining EFP species; in this case we separately report revenues from these mark-ups.

2.2. Analysis

The question we must evaluate is "what would have happened to 2014–2015 GHC outcome variables if the EFP had never occurred?" A common approach to imputing these counterfactual outcomes is to utilize the "before-after-control-impact" (BACI) (Stewart-Oaten et al., 1986) or "difference-in-differences" estimator (Angrist and Pischke, 2008) to compare the changes in outcome variables before and after a major policy change between a "treated" group and a nearly identical "control" group (e.g., Abbott and Wilen, 2010; Cunningham et al., 2016). While this approach has the benefit of controlling for intervening shared changes between treated and control groups, we avoid it due to ample evidence that the linchpin assumption of "common trends" between the EFP-treated vessels and our only candidate control group is violated (Appendix A in Supplementary material).[8] We build our statistical analysis upon longitudinal comparisons of 2014–2015 outcomes for EFP vessels only to years immediately preceding the EFP (2011–2013). While perhaps prone to biases from underlying trends in the intervening period (although these appear fairly muted), this approach establishes a fairly realistic ensemble of "status quo" scenarios of 1–1.5 month red snapper seasons and a July-Nov/Dec gag season.

We investigate the impacts of the EFP on 1) the seasonal reallocation of trips and landings; 2) trip offerings; 3) discards; and 4) net revenues.

Seasonal reallocation of trips and landings. Using the SRHS we examine both the total number and seasonal distribution of all trips and trips with retention of red snapper or gag. We also assess how landings of these species were spread over the season in 2014–2015 compared to

[7] Fuel use, as one of the largest expenditures, is most reliably estimated, while bait and ice are more approximate. Crew compensation data (before tips) are generally reliable, while compensation of captains is confounded by the fact that many captains are owner-operators.

[8] We also reject BACI due to the dubious relevance of 2014–2015 data for non-GHC vessels as a future scenario for policymakers evaluating the likely consequences of a permanent headboat catch share program. These years were marked by dramatic, idiosyncratic management changes that undermine the value of extrapolating treatment effects from the BACI scenario. In particular, 2014 saw an unprecedented 9 day recreational season for red snapper, followed by a 45 day for-hire red snapper season in 2015.

prior years. To determine how average landings per angler evolved, we estimate a regression on the trip data separately for red snapper, gag, and all catch:

$$FishPerAngler_{vt} = \alpha_v + \mu_{month} + \beta_{year} + \varepsilon_{vt} \quad (1)$$

where v indicates vessel and t indexes trips. The β_{year} coefficients are the parameters of interest and are a series of indicator (dummy) variables for each year. Throughout, we omit the dummy variable for 2013 in order to interpret our estimates relative to the last year before the EFP. μ_{month} are coefficients for the month of year to control for seasonality. We estimate a separate intercept for each vessel α_v. This "fixed effects estimator" subtracts vessel-specific means from each independent and dependent variable prior to ordinary least-squares estimation, allowing us to focus on *changes* over time for individual vessels, free from the potentially confounding effects of vessels' omitted time-invariant heterogeneity in landings rates and variations in the number of trips by vessel over the years (Wooldridge, 2010). We weight each observation by the number of anglers per trip. All reported confidence intervals use heteroskedasticity-robust standard errors (Wooldridge, 2010) except where noted.[9]

Trip offerings. We focus on how the EFP altered the allocation of trips between partial-day and full-day trips, where a "daytrip" is any trip of at least 8 but less than 15 h. We estimate a logistic regression on the trip data (dependent variable = 1 if a daytrip and = 0 otherwise) using the same independent variables as in Eq. (1) but adding a control for whether a trip occurs on the weekend or not. To examine how the propensity for a daytrip changed for different trip types we estimate the model for subsets of trips retaining EFP species, trips with no EFP species, and all trips. We report odds ratios for the annual dummy variables, where 2013 is normalized to one.

Some vessels reported lowering the maximum daily bag limit on their partial-day trips. To examine this practice, we regress 2014 GHC members' trip-level red snapper retention per angler for all partial- and full-day trips on annual dummy variables and their interaction with full-day trips, along with controls for month, vessels and weekend fishing. We weight observations by the number of anglers per trip. The interactions between annual dummies and the full-day indicator allow us to examine the evolution of the wedge in retention between trip durations.

Discards. We utilize two complementary discard rate measures. The first utilizes total catch of the species in question as the denominator. We regress trip-level discard rates, for all trips with positive catch of the species, on annual and vessel dummies.[10]

Our second measure is discards per angler-day and describes the amount of discards per unit of service provided on a trip. We estimate a Poisson regression with the number of discards as the dependent variable and with angler-days serving as an exposure variable (Cameron and Trivedi, 2013) (i.e. its coefficient is constrained to = 1) and with annual and vessel dummies as dependent variables. We report the incidence rates for the yearly dummies (the exponentiated coefficients) from this regression and report confidence intervals based upon standard errors that are robust to heteroskedasticity and incorrect specification of the likelihood (Gourieroux et al., 1984; Zeger and Liang, 1986).

Discards per angler-hour can be reduced in two ways, increasing the landed fraction of catch, or reducing the catch rate (CPUE), as reflected in the following identity:

$$\frac{Discards}{AnglersXhours} \equiv \frac{Discards}{Catch} \times \frac{Catch}{AnglersXhours} \quad (2)$$

To examine the role of reduced CPUE in influencing discards, we estimate truncated Poisson regression with the catch of each EFP species as the dependent variable, with vessel fixed effects and annual dummy variables as covariates and angler-hours as the exposure variable. The regression is truncated due to the need to condition on trips with positive catch.

Net Revenues. We calculate total revenues and net revenues for EFP members, with and without premium pricing for trips with retention of EFP species, and examine how these measures were distributed throughout the year. We also examine three pathways by which (net) revenues may have been affected by the EFP: 1) a quantity effect (either an increase in trips or an increase in customers per trip); 2) a product mix effect (shifting customers toward higher value or lower cost trips); or 3) charging a price premium for EFP-retaining trips. To investigate the potential for a quantity effect through increased anglers per trip we first regress the logarithm of trip revenues and net revenues on annual dummy variables and vessel fixed effects to identify evidence of post-EFP revenue changes at the trip level. We then repeat this regression for anglers per trip.

To investigate the product mix effect, we regress (log) revenue and net revenues per customer by trip on annual dummy variables and vessel indicators, weighting by the number of customers per trip. Since all prices in our revenue calculations are fixed at 2014 levels, any post-EFP changes occur solely due to changes in the mixture of trips and the allocation of customers across trips.

To assess the effect of price markups on revenues, we compare 2014–2015 total revenues with and without the premium for the relevant vessels. However, this comparison assumes the markups had no effect on demand. To test this hypothesis, we create as similar a comparison group as possible by restricting the sample to only EFP-species-retaining trips on vessels in Texas and Northwest Florida (where the vessels charging a mark-up were based). We then regressed the number of customers per trip on the size of the mark-up (including zero if a markup was not charged), including indicator variables for vessels, week, day of week, trip length, and whether the trip occurred during the red snapper season as controls. We also estimate a model that repeats the previous regression but with estimated trip revenues as the dependent variable.

3. Results

3.1. Seasonal reallocation of EFP trips and landings

The quantity and seasonal timing of trips for the GHC fleet did not change significantly in 2014 and 2015 (Fig B1, SI). However, this stability masks important adaptations to better match the pattern of customer demand. Fig. 1 presents the seasonal pattern of trips retaining red snapper or gag and landings of these species in years before and after the EFP. It shows that, despite the persistence of an uptick of red snapper fishing during the traditional early-June red snapper season in 2014–2015, both trips and red snapper landings are much more smoothed over the season. Nearly a third of red snapper trips occurred before the red snapper season opened in both years of the EFP, and vessels extended their allocation to accommodate an August fishery that had not existed since 2009.[11] Roughly half of 2014–2015 gag trips were taken before the beginning of the July 1 season – showing an even more extensive degree of seasonal smoothing of trips and landing. Overall, 2014 GHC member vessels saw the number of customers on

[9] Since two vessels joined the EFP in its second year, we interact an indicator for these vessels with the 2014 annual dummy so that the baseline 2014 dummy refers only to vessels in the GHC that year.

[10] We do not include seasonal controls since we want to allow for post-EFP changes in timing of trips to be included in our estimates of the EFP's influence.

[11] The causes of the small increase in red snapper trips during the fall are uncertain. In 2014, the potential for a summer/fall closure of the entire recreational fishery pursuant to 16 U.S.C. § 1883(d) triggered by private angling, charter vessels, and non-EFP headboats may have lead some GHC vessels to fish more aggressively early in the season to avoid losing any leftover allocation in the fall. In 2015, the GHC received significantly smaller initial allocations, which may have made it challenging for vessels to preserve quota for the fall fishery.

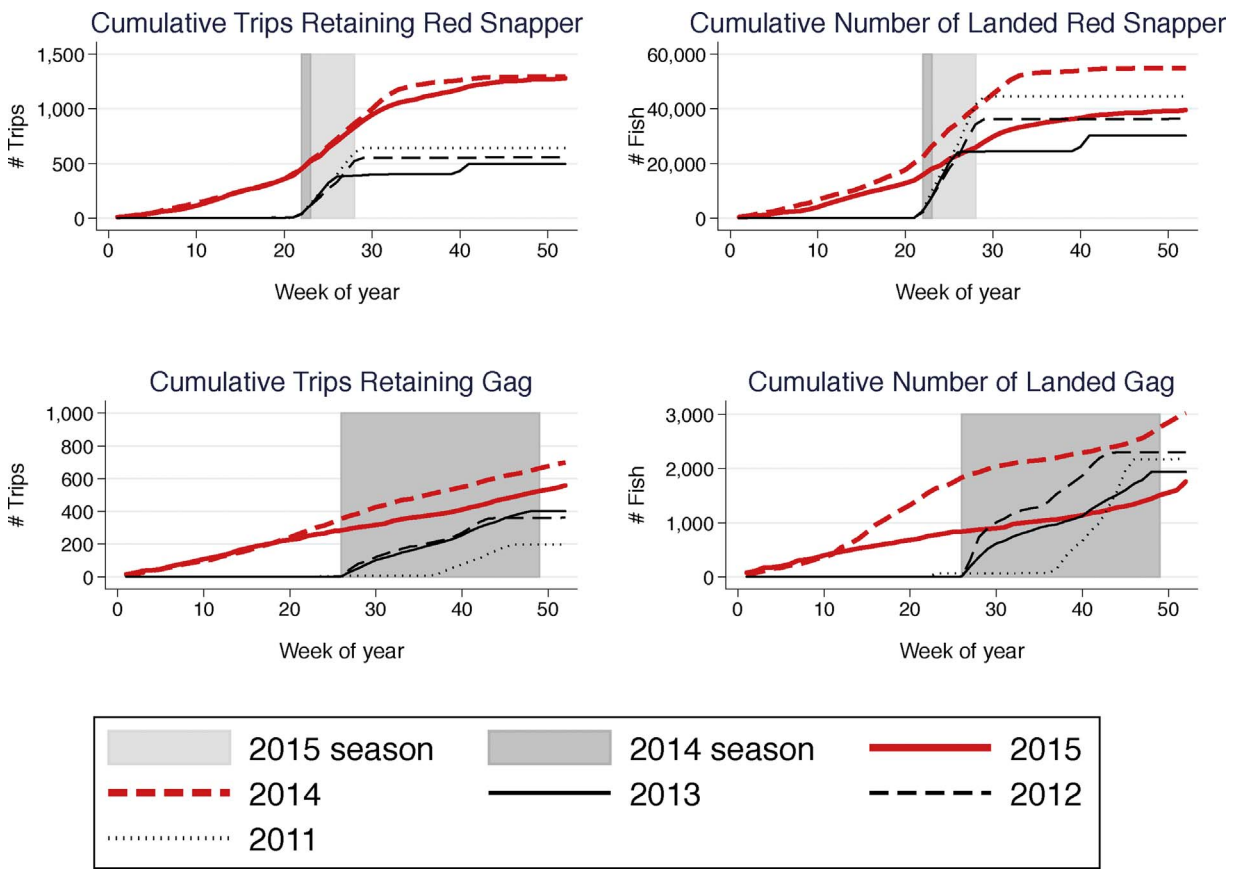

Fig. 1. Cumulative trips and landings of red snapper and gag for 2014 GHC vessels. GHC vessels that joined in 2015 are excluded so that comparisons before and after the EFP are for a stable cohort of vessels. The 2014 and 2015 gag season opening/closure dates were identical.

trips retaining either EFP species increase by 33,646 (117%) in 2014 and 25,829 (90%) in 2015 relative to 2013 (Fig B2, SI). This reflects a considerable broadening of access to these target species.

The increase in the number of trips retaining EFP species far exceeds the annual increases in landings of either species (Fig. 1). Trips keeping red snapper increased by 161% in both 2014 and 2015 relative to 2013, while landings, being constrained by quota allocations, increased by 82% (2014) and 31% (2015). Trips retaining gag increased by 74% (2014) and 39% (2015) relative to 2013, while gag landings increased by 56% in 2014 and actually *decreased* by 9% in 2015 relative to 2013. This implies that the average number of EFP species landed by the typical angler on these trips must have declined.

Fig. 2 shows that landings of red snapper per angler indeed fell by almost 0.4 fish (2014) and 0.66 fish (2015), from a 2013 average of 1.7 fish. This concurs with statements from some GHC operators that they often limited retention of red snapper outside of the federal season to 1 fish per angler, despite a legal limit of 2 fish/angler. Reductions in retention of gag have been small by comparison (Fig. 2), but are non-trivial given that average gag retention in 2013 was only 0.2 fish/angler on gag trips. There is, however, no evidence that anglers experienced reductions in their total landings of all species. 2014 total landings per angler are indistinguishable from 2013 levels, while 2015 total retention increased by half a fish on average (Fig. 2). This suggests that GHC vessels substituted toward non-EFP species, ensuring that customers went home with a full, diverse bag of fish while also providing access to red snapper and gag out of season.

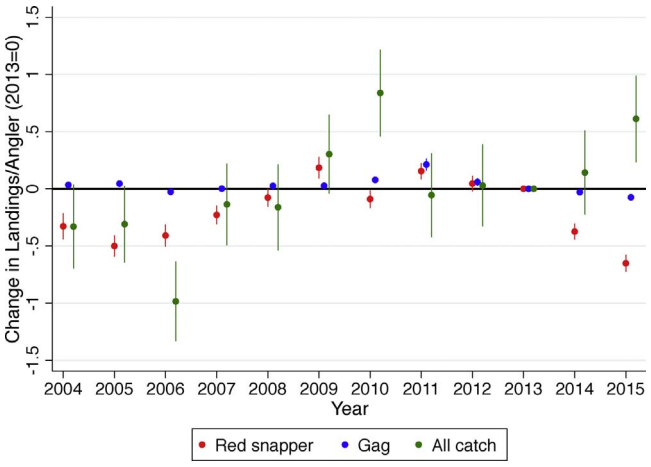

Fig. 2. Change in landings of red snapper, gag, and all species per angler on trips retaining the species or group of species in question. Results are from regressions of trip-level per-capita landings on annual dummies, vessel fixed effects and month dummy variables to control for seasonality. The regression is weighted by anglers per trip. The whiskers indicate 95% confidence intervals using robust standard errors.

3.2. Changing trip offerings

Before the EFP partial-day trips (< 8 h) were almost 55% of trips, while full-day trips (8 to < 15 h) comprised 43% of trips, with multi-day trips taking the remaining 2%. After the EFP, the share of full-day trips increased on several GHC vessels, especially in 2014 (Fig B3, SI). The odds of a full-day trip were 1.95 ($Z = 7.50$) and 1.23 ($Z = 2.27$) times greater in 2014 and 2015 than in 2013–rates that match or exceed any observed since 2004. The probability of a day trip increased by an average of 0.06 in 2014 and 0.02 in 2015.

The increase in EFP-species-retaining trips was complementary to the increase in full-day trips for many GHC vessels. The odds of a daytrip for trips retaining EFP species in 2014 and 2015 were 2.7

($Z = 6.77$) and 2.5 ($Z = 6.16$) times those in 2013 (Fig B3 SI). However, the odds of a daytrip for trips not retaining EFP species plummeted to 0.5 ($Z = -3.97$) and 0.25 ($Z = -9.53$) of 2013 levels. We find that the probability of a daytrip on trips retaining EFP species increased by 0.10 (0.09) in 2014 (2015), while the probability of a daytrip for trips not retaining red snapper or gag *fell* by 0.04 in 2014 (0.09 in 2015). Many GHC vessels disproportionately allocated EFP landings toward their existing full-day trips, while others, particularly in 2014, increased the share of full day trips in their offerings.

Utilizing results from the regressions of red snapper retention per angler, we find that the average wedge in red snapper retention between full- and partial-day trips in 2013 was only 0.16 fish/angler, supporting anecdotes that many anglers were able to fill their 2-fish bag limit on partial-day trips. However, we find that this gap rose to 0.5 fish/angler ($Z = 6.0$) in 2014 and 0.44 fish/angler ($Z = 4.79$) in 2015–the largest since 2007, when vessels operated under a 4-fish bag limit. These changes confirm many operations' reports that they have purposefully enforced sub-legal bag limits on shorter trips in order to stretch their allocations, while allowing fishermen on full-day trips to catch the full 2-fish bag limit.

3.3. Discards

In 2013 6.8 of every 10 red snapper and 8.6 of every 10 gag that were caught were subsequently discarded. After the EFP, red snapper discard as a share of catch fell an average of 28% (2014) and 34% (2015) compared to 2013, while gag rates fell 21% (2014) and 18% (2015) (Fig. 3). These are the lowest discard rates since 2008 for either species. These reductions are caused by decreases in mandatory regulatory discards during formerly out-of-season times of year, as discard rates during the 2014–2015 red snapper/gag seasons are comparable to previous years. Importantly, these reductions in discards were limited to the GHC fleet. Non-GHC discard rates as a share of catch increased 16% in 2014 and fell by 4% in 2015 relative to 2013 levels for red snapper, while 2014 and 2015 gag discard rates were statistically indistinguishable from 2013 levels (Fig B5, SI).

Discards per angler-hour also fell dramatically (Fig. 3). Average GHC red snapper discards per angler-hour fell by 41% (2014) and 47% (2015) – the lowest rates since 2006. Reductions were even more dramatic for gag, at 58% and 66%, respectively – the lowest rates since discard data became available in 2004. Discards per angler-hour declined by even more than discards as a share of catch, suggesting catch rates per angler-hour declined as well (Eq. (2)). Indeed, red snapper CPUE declined by 8% in 2014 and 23% in 2015, while gag CPUE saw far larger declines of 47 and 62% in 2014 and 2015, respectively (Fig B4, SI). Therefore, reductions in GHC discards per angler-hour were the joint product of increased retention rates and reduced CPUE for EFP species. The reductions in CPUE could potentially be explained by changes in biomass or its availability to headboats. However, while measures of local abundance of EFP species are lacking, estimated GOM biomass of both red snapper and gag increased over the study period (Gulf of Mexico Fishery Management Council 2015; SEDAR 2016). This suggests headboat operators played a substantial role in influencing CPUE by directing their effort toward other, non-EFP species during trips (see Section 3.1) – perhaps motivated by the need to conserve quota over the extended season.

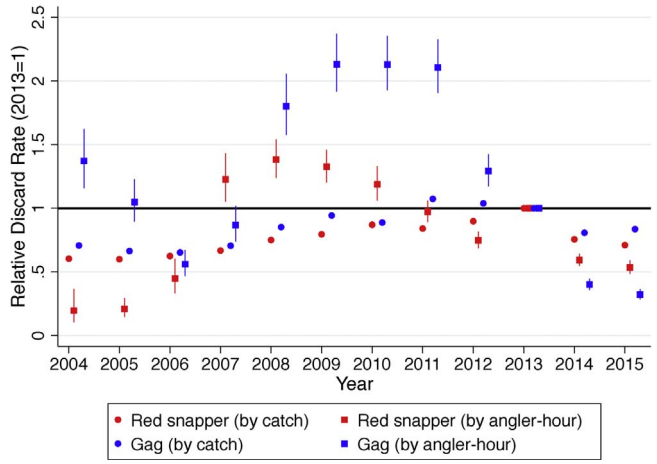

Fig. 3. Relative red snapper and gag discard rates, per unit of catch and angler-hours, for GHC vessels. The whiskers indicate 95% confidence intervals using robust standard errors.

Table 1
Estimated revenues for 2014 GHC vessels. Estimates are calculated at constant 2014 trip prices, input prices and input usage. Percentage changes are measured year-over-year. Percentage change for 2015 w/premium is calculated relative to 2014 levels w/premium.

	Revenue (millions US $)	% Chg.	Rev – fuel (millions US $)	% Chg.
2009	6.91		5.98	
2010	5.87	−15.12%	5.08	−15.06%
2011	8.28	41.03%	7.27	43.23%
2012	8.35	0.84%	7.35	1.08%
2013	8.45	1.18%	7.32	−0.48%
2014	**9.09**	**7.60%**	**7.86**	**7.39%**
w/premium	**9.20**	**8.94%**	**7.97**	**8.93%**
2015	**8.96**	**−1.37%**	**7.81**	**−0.63%**
w/premium	**9.05**	**−1.63%**	**7.89**	**−0.95%**

The bold typeface indicates the years of the policy experiment.

3.4. Changes in (Net) revenues

Table 1 shows that revenues, not including premia for trips retaining EFP species, increased by 7.6% in 2014 and 6.1% in 2015 relative to 2013 levels. Including mark-ups increases overall revenues by an additional 1.3% (2014) and 1.1% (2015). Revenues net of fuel costs increased by 7.4% in 2014 and 6.7% in 2015 relative to 2013. Including mark-up pricing lead to increases in net revenues of 8.9% and 7.9%. In 2014, the seasonal distribution of revenues is similar to previous years, albeit with revenues shifted slightly earlier in the year (Fig B6, SI). In 2015, this shift is more dramatic, with a significant smoothing of revenues across the year.

The total number of GHC trips in 2014 was unchanged from 2013 (Fig B1, SI), implying that the only quantity effect on revenues must work through the number of anglers per trip. Fig. 4 shows that revenues per trip increased by 9.5%, while anglers per trip increased by 6.3% (~2 extra passengers per trip). Therefore, roughly 2/3 of the increase in 2014 trip-level revenues came from serving more passengers per trip. In 2015 revenues per trip grew by a more modest 3.5% relative to 2013 levels. Anglers per trip increased by only 1.1% relative to 2013 on average, so that less than 1/3 of the increase in revenues per trip was attributable to increased customers.[12]

Considering the product mix effect, the average customer generated 2.3% more revenue in 2014 and 1.3% more in 2015 compared to 2013, holding prices constant at 2014 levels (Fig. 5). While these effects may seem small, they reflect a clear departure from historical patterns. The primary mechanism for this change is the aforementioned shift towards full-day trips at the expense of partial-day trips; removing these trips from the data erases any evidence of increases in revenue per customer in 2014–2015. We find that the average full-day trip yields 35% greater average revenue per customer and 31% greater average net revenue relative to partial-day trips. The shift of customers toward full-day trips

[12] While the increase in anglers per trip in 2015 was modest, the overall quantity effect was more substantial due to the fact that the total number of trips increased by 5.4% compared to 2013 (Fig B1, SI). This largely explains how revenues, before any price premium for EFP trips, increased by 6.1% in 2015 relative to 2013.

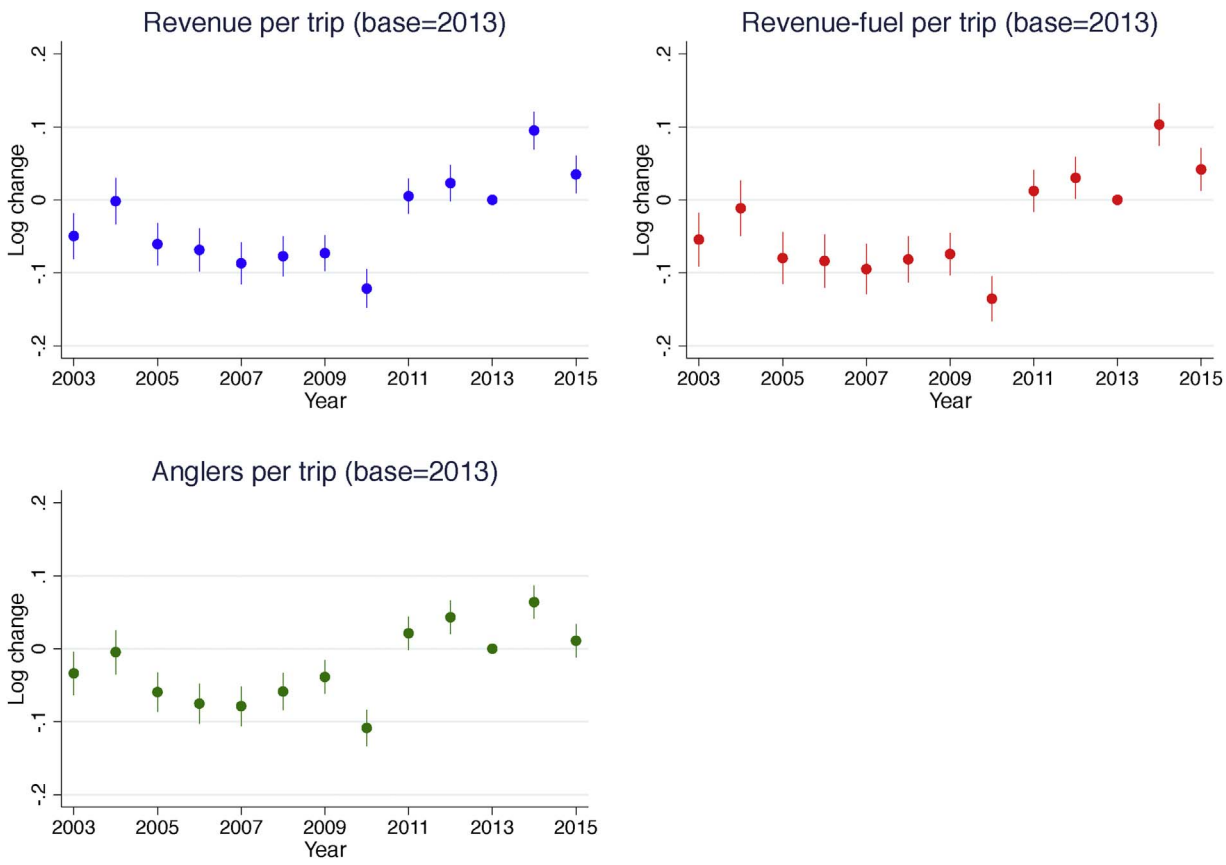

Fig. 4. Estimates of annual dummy variables from regressions of trip-level revenues, revenues minus fuel costs, and anglers per trip on vessel fixed effects. The sample is for 2014 GHC vessels only. The fixed effects control for time constant differences (i.e. capacity) to examine if vessels, on average, see increases or decreases in revenues and anglers per trip. The whiskers indicate 95% confidence intervals using robust standard errors.

was likely facilitated by the flexibility afforded under the EFP to shift landings of EFP species toward trips yielding higher returns.

A total of 5 (3) vessels in 2014 (2015), representing 9.6% of all trips in the post-EFP period, charged a premium for trips targeting EFP species. These mark-ups ranged from $5 to $20 and increased the price by 13% on average. These mark-ups increased GHC revenues by slightly more than 1%, if these mark-ups had no effect on customer demand (Table 1). Our test of this assumption finds no evidence of a significant negative effect of an increase in the premium on the number of customers per trip ($\beta = 0.004$, $Z = 1.86$). We also find that a $1 increase in premium for trips retaining EFP species yielded an average of $38 ($Z = 5.27$) in extra revenue per trip. Since the average trip carries 32 passengers, our estimates suggest that the premia simply resulted in proportional increase in revenues, with minimal, if any, effect on trip demand.

Given the dramatic shift of landings and trips retaining EFP species from the summer to earlier and later months, a stronger causal case can be made between the EFP and revenue increases if most of the post-EFP revenue increases can be traced to these offseason times. Repeating the analyses in Fig. 4 for subsamples including June-August and the remainder of the year, we find that summer trip revenues and anglers per trip were indeed stagnant in 2014–2015 but increased dramatically during the non-summer months (Fig B7, SI).

An analogous sub-setting of the analysis in Fig. 5 by seasons finds that the shifting of customers toward longer, higher-priced trips was also purely an off-season phenomenon (Fig B8, SI). Furthermore, if we tunnel down even further within the off-season months and focus exclusively on trips that did not retain EFP species, we find no evidence of increased average net revenue per customer for these trips (Fig B9, SI). Together these findings substantiate that the strong product mix effects shown in Fig. 5 are heavily driven by the ability under the EFP to offer red snapper and gag trips outside the regular season. This corroborates anecdotal evidence from some headboat owners that they disproportionately allocated their quota toward longer, more profitable trips outside the summer months.

3.5. Responses from headboat owner surveys

3.5.1. Profitability and cost reductions

We elicited participants' assessment of the EFP on profits using the following question: *"On the whole, do you think your headboat business was more profitable in 2014 (2015) than it would have been if you had not participated in the Gulf Headboat Collaborative in 2014 (2015)? (YES/NO/ABOUT THE SAME)."* For the 2014 season, 12 owners answered "yes", while 1 answered "no." For the 2015 season, 11 owners responded "yes", while 3 indicated that they thought their profitability would have been "about the same" if they had remained outside the GHC.

Fig. 6 shows responses to a series of Likert scale rankings of which factors were most important for increased profits under the GHC. These included: 1) More customers per trip; 2) Charging a higher price for access to fish out of season; 3) Shifting customers to longer trips; 4) Running more trips; and, 5) Lower costs per trip. In both years, owners placed a strong priority on the role of the GHC in increasing the number of customers, both through increasing the number of trips and the number of anglers per trip. Lower costs are considered at least somewhat important for at least half of respondents in both years, while shifting customers to longer trips is given less importance overall. Charging a premium price for access to EFP species out of season is considered unimportant or of ambiguous importance by the majority of owners.

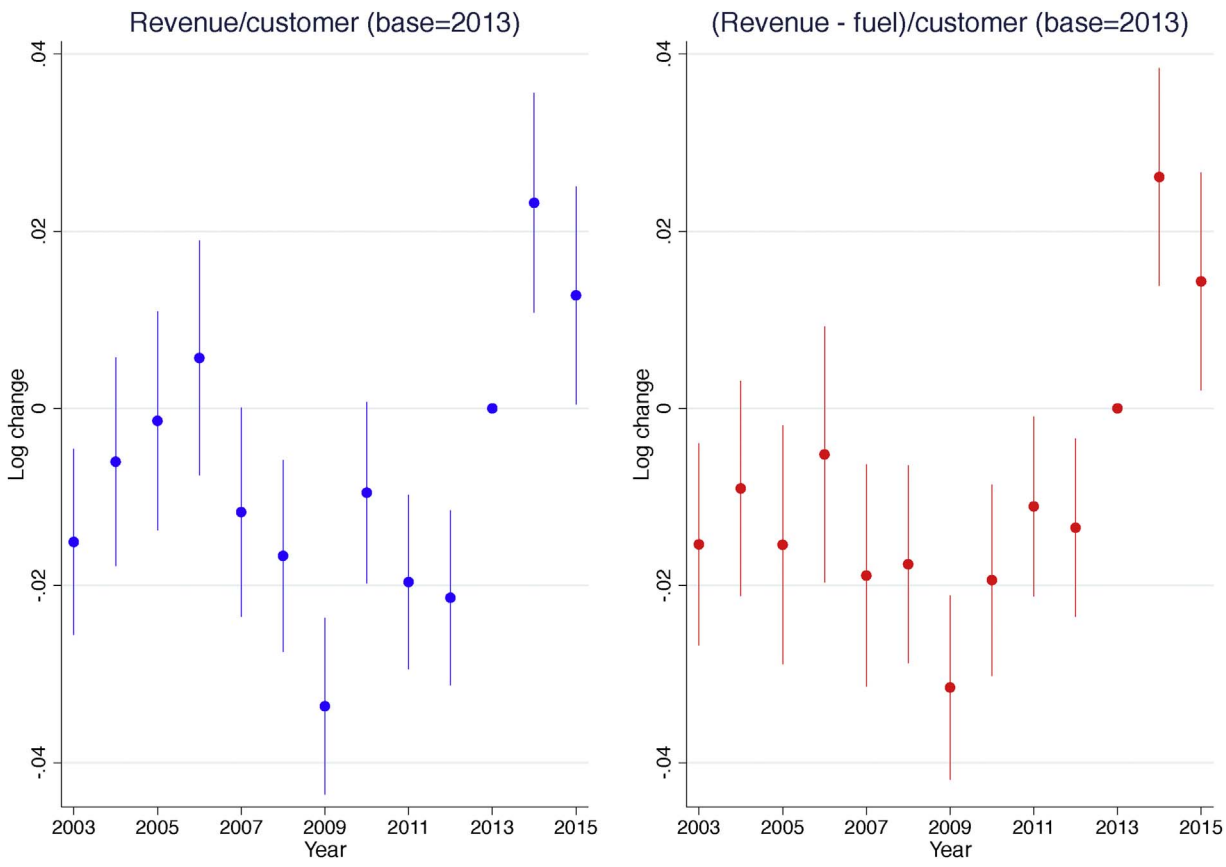

Fig. 5. Change in average revenue per customer and average revenue minus fuel costs per customer (relative to a base year of 2013). Results are from regressions of logged revenue per customer and revenue minus fuel costs per customer at the trip level. The regression includes vessel fixed effects. Each regression is weighted by the number of passengers per trip. The whiskers indicate 95% confidence intervals using robust standard errors.

3.5.2. Trip-taking in poor weather

We asked participants "*how (if at all) participation in the Gulf Headboat Collaborative altered your decision making with respect to weather and rough seas.*" In both survey years, 7 out of 14 companies indicated that their participation did not alter their cancellation decisions on rough weather days. In both years 4 respondents indicated that the increased security of red snapper or gag allocations lead them to err more on the side of safety and customer comfort. One response was typical: *"In 2014 we cancelled the trip if the weather forecast was marginal. We could use the quota on a later trip. In previous years, we made some trips when the forecast was marginal… These trips were not made in 2014 because we did not attempt to go on the marginal forecast days."*

3.5.3. Changes in business operations and overall assessment of the GHC

We asked the following question: *"Did you limit customers to 1 red snapper or gag per customer on any of your headboat trips in 2014? "* In 2014 (2015), 7 out of 14 (8 out of 14) respondents answered "no" to this question, while the rest indicated limiting customers to less than the legal bag limit on at least some trips. Several owners reported adapting to changing competitive conditions in their use of the lower bag limits, and even active experimentation:

- *"Yes, until June 1 when red snapper season opened up, then 2 per person afterward. People were okay with it." (2015)*
- *"On our 6-h winter trips and our summer 6-h trips, we did limit our*

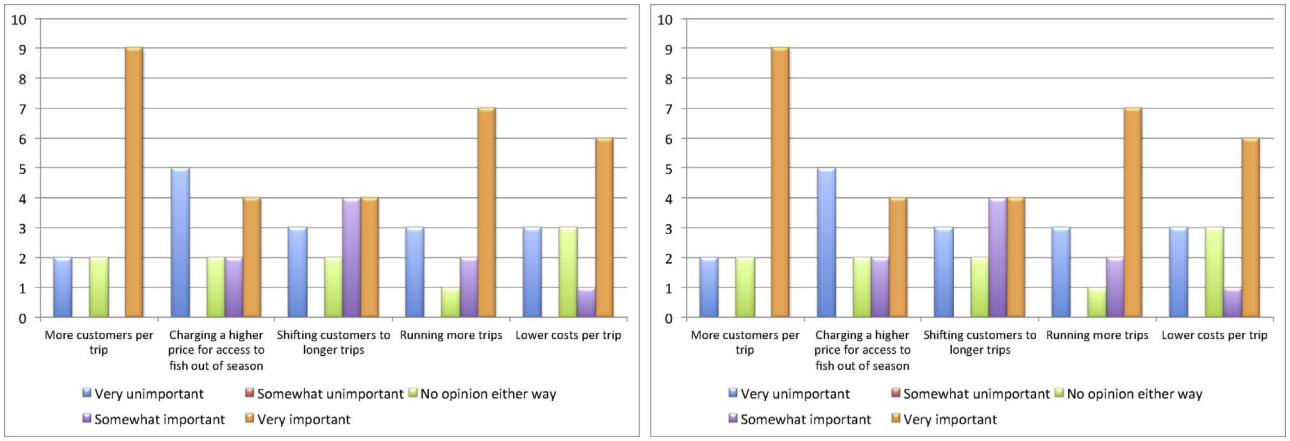

Fig. 6. Headboat owners' assessment of the importance of different potential contributors to increased seasonal profits under the GHC in a) 2014 and b) 2015.

customers to 1 red snapper per person. We would explain to our customers about the EFP and that we had an allocation of fish that we had to manage… Those customers who wanted a limit of red snapper were offered our 8-h trip." (2015)

- *"We had great success with limiting to 1 red snapper and/or 1 gag. We changed the limit in a variable nature to see if it had an impact on our booking and we found that trips with one snapper sold out as well as trips with two." (2014)*

To provide GHC operators with an open-ended opportunity to explain how their participation affected their way of doing business, we asked the following question: *"Can you comment on how (if at all) participating in the Gulf Headboat Collaborative changed your way of doing business in 2014 (2015)?"* There were several consistent themes in the responses. Several vessels reported that their participation allowed them to fish in a way that lowered their fuel costs:

- *"We were able to run more 6 h trips with minimal fuel consumption because we knew the snapper would be there to catch and we didn't have to waste valuable time and fuel to try to locate other species." (2014)*
- *"We offered the same types of trips as normal, but our expenses were reduced primarily because we did not have to use more fuel searching for other types of fish."* (2015)

Some vessels reported changes in their trip offerings or timing:

- *"We ran more extended trips. We charge more for these specialty trips and only ran them to target ARS (American red snapper) and gag." (2014)*
- *"The GHC allowed us to run more customers and trips on both sides of the regular season, and it also allowed access to our spring and winter customers that had been excluded from the red snapper fishery for a very long time. We did offer less trips and more longer trips to conserve fishing quota." (2015)*

Some vessel owners indicated that the program lead to increased demand:

- *"It did not change the way we did business. It did affect the rate of repeat customers which helped revenue." (2014)*
- *"The ability to offer red snapper trips year around was the most important source of increased profit. Those who would not typically fish because they could not catch red snapper were now willing to spend the money to go out fishing." (2015)*

These responses should be treated with caution, as GHC members may have a vested interest in the success of the EFP. Nevertheless, our empirical analysis substantiates owners' testimony of increased profits and validates the relative importance of the contributing mechanisms − suggesting that survey responses provide a complementary perspective of the EFP's effects.[13]

4. Discussion

The results of any case study are intertwined with their local context. Synthetic evaluation (e.g., Ostrom 1990) of multiple cases is ultimately needed to generate reliable, broadly transferable knowledge. Nevertheless, RBM is in its infancy in for-hire fisheries, and so single case studies are critical to building this knowledge. This parallels the development of understanding about commercial RBM, where accumulation of knowledge from individual cases (e.g., Annala, 1996; Arnason 2005; Dewees 1998) preceded the flowering of synthetic studies (e.g., Costello et al., 2008; Essington et al., 2012).

As an early experimenter with RBM, some aspects of the local context for the GOM EFP were uniquely favorable. Research on the emergence of property rights (e.g., Libecap 1993) and experience from commercial RBM cases suggest that adoption of for-hire RBM is mostly likely in cases where economic dissipation under existing management, coupled with sound biological management, allow for significant short-run gains from RBM to industry participants. This describes the GOM fishery well. Cascades of tightening regulation, accelerated by strong customer demand for recovering species, made continuation of "business as usual" expensive − driving a group of vessel owners to overcome the collective transaction costs to pursue an alternative. This group was able to overcome these transaction costs due in part to the efforts of an NGO, which helped shepherd the EFP through political challenges and the labyrinthine policy process. Furthermore, the comparatively strong regulation of the headboat sector through permits and catch reporting greatly facilitated RBM adoption by providing the data to establish a 'grandfathered' allocation to the cooperative. This, and the small number of headboats compared to charter vessels, is a critical reason why the EFP was limited to headboats.

Despite its limitations, the Gulf of Mexico headboat EFP represents an unusual experiment in adaptive management (Walters 1986), to anticipate the consequences of permanently implementing RBM in the for-hire sector. The experimental allocation of potential year-round fishing privileges to 19 vessels generated considerable acrimony among other recreational fishing businesses and anglers constrained by short seasons. Nevertheless, two EFP-inspired management proposals to extend RBM to the entire GOM for-hire sector were initiated before the EFP had expired (Gulf of Mexico Fishery Management Council 2016a,b). The data from this policy experiment reveal a number of outcomes that are likely to replicate under similar permanent programs. These include: 1) a smoothing of allocated species across the season, increasing access to these species for a wider population of anglers; 2) a reduction in the landings of allocated species per customer throughout the season relative to during "derby" fisheries, complemented by substitution toward alternative valued species; 3) a reduction in regulatory discards due to greater flexibility in allocating quota to the temporal profile of catch; and 4) increases in profits from the ability to utilize vessels' quota allocation to provide fishing trips to customers that better match and, potentially, stimulate the patterns of customer demand across ports and seasons.

There are reasons to expect business innovations under a permanent, sector-wide program beyond those seen during the EFP. Some innovations require sufficient time to engage in "learning by doing" under a new regulatory regime. However, it is probable that some innovations, which may have occurred rapidly under a permanent policy change, were forestalled in a temporary program due to switching costs or concerns about alienating customers with short-lived changes in business practices.

One outcome that seems unlikely to persist is the reticence to reflect the scarcity of red snapper and gag quota in the pricing of trips. In a system with transferability of quota across vessels, even owners that choose not to fish their full allocation will be induced to consider the opportunity cost of supplying this quota to other vessel owners. Therefore, we predict that this cost will ultimately be reflected in the pricing of trips under a permanent program. Since some customers care more about targeting and retaining certain species than others, we expect that headboat operators will develop differentiated trip offerings, with higher pricing for trips targeting scarce species valued by particular segments of anglers, but with lower prices aimed at those not possessing such values.

The inelastic response to price increases for retention of EFP species may not persist under a permanent program. This may be driven by a combination of the novelty of the opportunity to retain red snapper or

[13] For example, in 2014, 9 out of 11 respondents said that increasing the number of customers per trip was very important for profits, but this number declined to 3 out of 13 in 2015. This decline is consistent with the reduced role of this contributor to estimated profits in 2014 vs. 2015 (Fig. 4).

gag out of season and a lack of competitors offering similar trips in nearby ports. Under a permanent program such privileges would be distributed over approximately 70 headboat vessels − allowing customers to select the operation with the best trips and pricing while fostering price-reducing competition.

Individual anglers tend to have heterogeneous preferences for catch and landings within and across species that may differ systematically along regional and seasonal gradients within the same fishery (Hunt 2005; Post et al., 2008; Johnston et al., 2010). Conventional instruments such as bag limits and season closures typically fail to allocate landings efficiently across anglers (Holzer and McConnell 2014) and may create undesirable distributional consequences. For example, season openings may allocate scarce landings of a high-value species to casual anglers that happen to be present during the season, even though those anglers may value the catch less than local anglers that are unavailable during the season or that would prefer to fish in less congested conditions. Seasons may also fail to account for spatiotemporal variability in species abundance or the occurrence of inclement weather. Similarly, bag limits may constrain the landings of skilled, often more avid, anglers − forcing them to bear the cost of an additional trip if they desire to catch additional fish − while often doing little to limit the take of less skilled anglers (Cox et al., 2002).

The advantage of an allocation-based approach, such as cooperatives or IFQs, is that each operation is able to adapt its trip offerings, pricing and marketing to reflect its local context. The likely result is a more differentiated for-hire market than currently exists under the existing "one-size-fits-all" approach. Vessel owners can profit through differentiation of their product, and customers can benefit by selecting from a richer menu of trip types. With adequate competition in the for hire sector, this product differentiation will tend to enhance overall angler welfare by allowing those who place the highest value on landing managed species to access them through a marketplace that lets anglers fish when and how they like, while ensuring accountability in the use of public resources.

Extending rights-based management to for-hire recreational fisheries presents significant challenges. First, as with commercial fisheries, the determination of the initial allocation of quotas may be contentious. Second, developing adequate programs for the monitoring and enforcement of quotas at the vessel level may require substantial upfront public investments since individual for-hire vessels are typically lightly monitored. Third, developing an industry culture of accountability and professionalism in compliance and data provision may require substantial outreach and training investments on the part of fishery managers or non-governmental organizations, as well as strong internal leadership within the industry due to the wide range of operator types that may be present in a given fishery. Despite these challenges, the results from the GHC policy experiment suggest that rights-based management is capable of providing substantial benefits for both for-hire operators and anglers.

Acknowledgements

We thank Andy Strelcheck, Jessica Stephen, and Kelly Fitzpatrick for their assistance in obtaining and explaining the SRHS data. We also thank Randy and Susan Boggs for their help in communicating with Gulf Headboat Collaborative members to ensure strong participation in the data gathering activities of this research. Finally, we are grateful to the members of the Gulf Headboat Collaborative for their cooperation with the research activities. Bethany Steele and Patrick Lloyd-Smith provided excellent research assistance.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.fishres.2017.08.014.

References

Abbott, J.K., Wilen, J.E., 2009. Rent dissipation and efficient rationalization in for-hire recreational fishing. J. Environ. Econ. Manag. 58, 300–314.
Abbott, J.K., Wilen, J.E., 2010. Voluntary cooperation in the commons? Evaluating the Sea State program with reduced form and structural models. Land Econ. 86, 131–154.
Abbott, J.K., Maharaj, V., Wilen, J.E., 2009. Designing ITQ programs for commercial recreational fishing. Mar. Policy 33, 766–774.
Abbott, J.K., 2015. Fighting over a red herring: the role of economics in recreational-commercial allocation disputes. Mar. Resour. Econ. 30, 1–20.
Anderson, L.G., 1993. Toward a complete economic theory of the utilization and management of recreational fisheries. J. Environ. Econ. Manag. 24, 272–295.
Angrist, J.D., Pischke, J.-S., 2008. Mostly Harmless Econometrics: An Empiricist's Companion. Princeton University Press, Princeton, NJ.
Annala, J.H., 1996. New Zealand's ITQ system: have the first eight years been a success or a failure? Rev. Fish Biol. Fish. 6, 43–62.
Arnason, R., 2005. Property rights in fisheries: iceland's experience with ITQs. Rev. Fish Biol. Fish. 15, 243–264.
Arnason, R., 2012. Property rights in fisheries: how much can individual transferable quotas accomplish? Rev. Environ. Econ. Policy 6, 217–236.
Borch, T., 2010. Tangled lines in New Zealand's quota management system: the process of including recreational fisheries. Mar. Policy 34, 655–662.
Cameron, A.C., Trivedi, P.K., 2013. Regression Analysis of Count Data. Cambridge University Press.
Coleman, F.C., Figueira, W.F., Ueland, J.S., Crowder, L.B., 2004. The impact of United States recreational fisheries on marine fish populations. Science 305, 1958–1960.
Costello, C., Gaines, S.D., Lynham, J., 2008. Can catch shares prevent fisheries collapse? Science 321, 1678–1681.
Cox, S.P., Beard, T.D., Walters, C., 2002. Harvest control in open-access sport fisheries: hot rod or asleep at the reel? Bull. Mar. Sci. 70, 749–761.
Cunningham, S., Bennear, L.S., Smith, M.D., 2016. Spillovers in regional fisheries management: do catch shares cause leakage? Land Econ. 92, 344–362.
Deacon, R.T., 2012. Fishery management by harvester cooperatives. Rev. Environ. Econ. Policy 6, 258–277.
Dewees, C.M., 1998. Effects of individual quota systems on New Zealand and British Columbia fisheries. Ecol. Appl. 8, S133–38.
Doerpinghaus, J., Hentrich, K., Troup, M., Stavrinaky, A., Anderson, S., 2014. An assessment of sector separation on the Gulf of Mexico recreational red snapper fishery. Mar. Policy 50, 309–317.
Essington, T.E., et al., 2012. Catch shares, fisheries, and ecological stewardship: a comparative analysis of resource responses to a rights-based policy instrument. Conserv. Lett. 5, 186–195.
Fenichel, E.P., Abbott, J.K., 2014. Heterogeneity and the fragility of the first best: putting the micro in bioeconomic models of recreational resources. Resource Energy Econ. 36, 351–369.
Fenichel, E.P., Abbott, J.K., Huang, B., 2013. Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature. Fish Fish. 14, 137–157.
Figueira, W.F., Coleman, F.C., 2010. Comparing landings of United States recreational fishery sectors. Bull. Mar. Sci. 86, 499–514.
Gourieroux, C., Monfort, A., Trognon, A., 1984. Pseudo maximum likelihood methods: applications to Poisson models. Econometrica 52, 701–720.
Grafton, R.Q., et al., 2006. Incentive-based approaches to sustainable fisheries. Can. J. Fish. Aquat.Sci. 63, 699–710.
Gulf of Mexico Fishery Management Council, 2014. Recreational red snapper sector separation: Final amendment 40 to the fishery management plan for the reef fish resources of the Gulf of Mexico. December 2014.
Gulf of Mexico Fishery Management Council(2015) Standing and special reef fish SSC reviewof 2014 SEDAR 31 update assessment, January 6–8 2015. Tampa, Florida. Available at: http://sedarweb.org/docs/postsedar/Gulf%20Council%20SSC%20Review%20of%202014%20SEDAR%2031%20Update.pdf [Accessed 06, June 2017].
Gulf of Mexico Fishery Management Council, 2016a. Red snapper management for federally permitted charter vessels. Draft amendment 41 to the fishery management plan for the reef fish resources of the Gulf of Mexico. October 2016.
Gulf of Mexico Fishery Management Council, 2016b. Reef fish recreational management for headboat survey vessels. Amendment 42 to the fishery management plan for the reef fish resources of the Gulf of Mexico. Draft. August 2016.
Holzer, J., McConnell, K., 2014. Harvest allocation without property rights. J. Assoc. Environ. Resource Econ. 1, 209–232.
Hunt, L.M., 2005. Recreational fishing site choice models: insights and future opportunities. Hum. Dimens. Wildlife 10, 153–172.
Ihde, T.F., Wilberg, M.J., Loewensteiner, D.A., Secor, D.H., Miller, T.J., 2011. The increasing importance of marine recreational fishing in the US: Challenges for management. Fish. Res. 108, 268–276.
Johnston, F.D., Arlinghaus, R., Dieckmann, U., 2010. Diversity and complexity of angler behaviour drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. Can. J. Fish. Aquat. Sci. 67, 1507–1531.
Kearney, R.E., 2001. Fisheries property rights and recreational/commercial conflict: implications of policy developments in Australia and New Zealand. Mar. Policy 25, 49–59.
Leal, D., Maharaj, V., 2009. Evolving Approaches to Managing Marine Recreational Fisheries. Lexington Books, Lanham, MD.
Lewin, W.-C., Arlinghaus, R., Mehner, T., 2006. Documented and potential biological impacts of recreational fishing: insights for management and conservation. Rev. Fish.

Sci. 14, 305–367.
Libecap, G., 1993. Contracting for Property Rights. Cambridge University Press.
Lovell, S., Steinback, S., Hilger, J., 2013. The Economic Contribution of Marine Angler Expenditures in the United States, 2011. NOAA Technical Memorandum NMFS-F/SPO-134.
NOAA Fisheries Southeast Regional Office, 2016. Annual Catch Limits (ACL) Monitoring. Available at: http://sero.nmfs.noaa.gov/sustainable_fisheries/acl_monitoring/ [Accessed 26, December 2016].
NOAA Fisheries Southeast Regional Office, 2017. Historical recreational landings and annual catch limits. Available at: http://sero.nmfs.noaa.gov/sustainable_fisheries/acl_monitoring/recreational_historical/index.html [Accessed 05, June 2017].
NOAA Fisheries, 2014. Status of the stocks. Annual report to Congress on the status of U.S. fisheries. Available at: http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2014/2014_status_of_stocks_final_web.pdf. [Accessed 06, June 2017].
National Marine Fisheries Service Southeast Regional Office, 2015. Headboat collaborative pilot program 2014 annual report. Available at: http://sero.nmfs.noaa.gov/sustainable_fisheries/lapp_dm/documents/pdfs/2015/hbc_2014_annual_report_final.pdf [Accessed 26, December 2016].
National Marine Fisheries Service, 2016. Fisheries economics of the United States, 2014. U.S. Dept. of Commerce NOAA Technical Memorandum NMFS-F/SPO-163.
Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.
Pawson, M.G., Glenn, H., Padda, G., 2008. The definition of marine recreational fishing in Europe. Mar. Policy 32, 339–350.
Pitcher, T.J., Hollingworth, C.E., 2002. Fishing for fun: where's the catch? In: T. Pitcher, J., Hollingworth, C.E. (Eds.), Recreational Fisheries: Ecological, Economic and Social Evaluation. John Wiley & Sons, pp. 1–16.
Post, J.R., Persson, L., Parkinson, E.A., Van Kooten, T., 2008. Angler numerical response across landscapes and the collapse of freshwater fisheries. Ecol. Appl. 18, 1038–1049.
Reimer, M.N., Wilen, J.E., 2013. Regulated open access and regulated restricted access fisheries. In: Shogren, J.F. (Ed.), Encyclopedia of Energy, Natural Resource, and Environmental Economics. Elsevier Science B.V., pp. 215–223.
SEDAR, 2016. SEDAR 33 update report for Gulf of Mexico gag grouper. Charleston, South Carolina. http://sedarweb.org/docs/suar/GagUpdateAssessReport_Final_0.pdf [Accessed 06, June 2017].
Savolainen, M.A., Caffey, R.H. and Kazmierczak, R.F., 2012. Economic and attitudinal perspectives of the recreational for-hire fishing industry in the U.S. Gulf of Mexico. Final report to NOAA-Fisheries, Contract Number 674139B.
Stewart-Oaten, A., Murdoch, W.W., Parker, K.R., 1986. Environmental impact assessment: pseudoreplication in time? Ecology 67, 929–940.
Stoeven, M.T., 2014. Enjoying catch and fishing effort: the effort effect in recreational fisheries. Environ. Resour. Econ. 57, 393–404.
Timmins, C., Murdock, J., 2007. A revealed preference approach to the measurement of congestion in travel cost models. J. Environ. Econ. Manag. 53, 230–249.
Walters, C.J., 1986. Adaptive Management of Renewable Resources. The Blackburn Press.
Wilen, J.E., 2006. Why fisheries management fails: treating symptoms rather than the cause. Bull. Mar. Sci. 78, 529–546.
Woodward, R.T., Griffin, W.L., 2003. Size and bag limits in recreational fisheries: theoretical and empirical analysis. Mar. Resour. Econ. 18, 239–262.
Wooldridge, J.M., 2010. Econometric Analysis of Cross Section and Panel Data. MIT Press.
World Bank, 2012. Hidden Harvest: the Global Contribution of Capture Fisheries. World Bank, Washington D.C.
Zeger, S.L., Liang, K.-Y., 1986. Longitudinal data analysis for discrete and continuous outcomes. Biometrics 42, 121.