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ARTICLE

The Effect of Changes in Trip Costs and Gag Regulations on Recreational Fishing Demand in the Gulf of Mexico

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Abstract
The Gag *Mycteroperca microlepis* is one of the most popular reef fish targeted by anglers fishing in the Gulf of Mexico. Around 7% of all trips by private boat anglers fishing from the west coast of Florida in 2019 targeted Gag during the open season. We conducted a survey of private boat anglers in Florida and estimated a statistical model to predict changes in the number of fishing trips anticipated with changes in trip costs and Gag bag limits. We found that for the average angler, the economic value of each private boat trip is around US$200 and that a $10 increase in trip costs would decrease private boat fishing trips by 5%. We also found that, on average, private boat anglers targeting Gag would take 12% more trips if the bag limit was increased by one fish from the current bag limit of two fish. The results of our study will help to anticipate the extent to which recreational fishing effort and value could change when trip costs and Gag regulations change.

The Gag (also known as Gag Grouper) *Mycteroperca microlepis* is one of the most popular reef fish targeted by anglers fishing in the Gulf of Mexico (GOM). Around 7% of all trips by private boat anglers fishing from the west coast of Florida (WFL) in 2019 targeted Gag during the open season. In federal waters, the share of private boat angler trips fishing for Gag is even higher at around 22%.[1]

[1]On the west coast of Florida, federal waters begin at 10 nautical miles from the shore. These estimates are based on the Marine Recreational Fishing Program (MRIP) estimates for June–December 2019. The estimate in the text uses the MRIP definition of directed trips to include anglers who listed Gag as the primary or secondary target species.

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The recreational harvest of Gag in the GOM is managed with bag limits and fixed seasons, which are set to help the fishery stay within the annual catch limits (ACLs) set for the sector. Technically, the fishery is expected to close when the ACL is reached during the open season. However, identifying the point at which the ACL is met within the season has been challenging given lags in data reporting and processing.

The bag limit for Gag has been 2 fish/angler since 2009, but the seasons varied considerably until 2016, when the season in federal waters was set to open in June and continue through the end of the year. The minimum size limit was also set in 2016 to 24 in.[2] These regulations and related regulations in the commercial sector were implemented to protect the Gag stock, which was in decline during the early 2000s.

The most recent Gag stock assessment found that the fishery is overfished and experiencing overfishing and has a relatively low proportion of males, which endangers the stock's ability to reproduce. Consequently, the Gulf of Mexico Fishery Management Council is developing a rebuilding plan that will enable the stock to recover. The rebuilding plan will necessarily require changes to ACLs and other regulations, like bag limits and seasons. Changes in the allocation of allowable harvest between recreational and commercial sectors have also been considered. As the Gulf of Mexico Fishery Management Council weighs alternative policies, there will be a need to understand how changing regulations will affect patterns of recreational effort. There is also a need to predict effort when setting seasons and when tracking harvest levels within the season. The current research aims to improve our ability to predict changes in angler effort that are anticipated to occur with changes in Gag bag limits and seasons. We focus on anglers fishing in the GOM from the WFL because nearly all of the recreational harvest of Gag originates from this area.

Most economic studies of recreational fishing in the southeastern USA focus on the *value* of changes in catch rates or regulations for important species, such as Red Snapper *Lutjanus campechanus*, grouper, King Mackerel *Scomberomorus cavalla*, and Dolphinfish *Coryphaena hippurus* (Gillig et al. 2003; Hindsley et al. 2011; Carter and Liese 2012; Haab et al. 2012a, 2012b; Lovell and Carter 2014; Carter et al. 2020). There is less research on how marine anglers *respond* to changes in catch rates or regulations. Here, the dominant approach is to measure how anglers change the number of trips taken when *catch rates* change (e.g., Milon 1991; Gillig et al. 2000, 2003). Very little work has been done to measure trip changes in response to *regulations* like bag limits or season closures. This is important because, as shown by Carter et al. (2022), angler behavior in response to a bag limit change is different than the behavior associated with a change in the catch rate. Bag limit responses are typically less than responses to the catch rate because the bag limit response depends on the probability of catching the bag limit.

In the work most similar to the present research, Whitehead et al. (2011) investigated how anglers would change the number of charter trips they take in North Carolina in response to hypothetical changes in the bag limits for snapper, grouper, and King Mackerel. Their results suggested that charter anglers would take about 3.67% more trips on average for each one-fish increase in the bag limit for snappers and groupers.[3] Work in freshwater fisheries has also found that lower bag limits are associated with lower effort on average (e.g., Cox et al. 2002; Beard et al. 2003; Fayram and Schmalz 2006). However, a recent study that asked anglers how many trips they would take under hypothetical Louisiana Southern Flounder *Paralichthys lethostigma* regulation alternatives, including different bag (creel) limits, found that "the regulations presented in the survey would not significantly alter general angling behaviors or the economic values provided by coastal Louisiana angling" (Smith et al. 2022:9). Similarly, another recent study of the U.S. East Coast Striped Bass *Morone saxatilis* fishery found that while most anglers would not change their effort in the face of hypothetical bag limit increases, the share of anglers who said that they would increase their effort was twice the share of anglers who said that they would decrease their effort for the same bag limit increase (Murphy et al. 2019). These varying findings suggest that more work is necessary to measure the regulation response of anglers fishing in other areas and for other species.

We conducted an angler survey and estimated a statistical model to predict changes in the number of fishing trips anticipated with changes in trip costs and Gag bag limits in the GOM. Our approach combines actual and contingent behavior (CB) data to estimate a trip demand model (Alberini et al. 2007; Whitehead et al. 2011). The model provides estimates of changes in recreational fishing effort expected from changes in fishing costs and Gag regulations. The estimates can be used to develop predictive models that forecast how fishing effort will change when the trip costs change (e.g., via fuel price changes) and when the Gag fishing regulations (season length or bag limits) change. This will improve the analysis of the economic effects of proposed changes in fishing regulations and changes in economic factors that affect the cost of fishing, such as fuel prices.

METHODS

Survey sampling.— The Florida Boating and Fishing Survey (FBFS) was conducted in early 2020 to obtain

[2]The minimum size limit was set to 20 in during 1990 and 22 in during 2000. There is also a combined bag limit for a set of shallow-water grouper species, including Gag, that is currently five fish.

[3]The coefficient on the King Mackerel bag limit variable was not statistically different from zero.

information about Florida anglers' fishing activity in the GOM during November and December of 2019. The target population for the FBFS was any person with a boat registered in Florida who might have fished in the GOM during November and December.[4] We were especially interested in anglers fishing for Gag. There is no specific list for this type of angler. We constructed a sample frame from two lists: (1) the list of registered Florida boat owners (FBO) and (2) the list of licensed saltwater anglers in Florida (FLSA).[5] The FBO list contains boat-based anglers who are missing from the saltwater license list due to exemptions, especially adults 65 and over, which make up nearly 20% of the Florida population and by some accounts around 15% of the angling population (U.S. Fish and Wildlife Service and U.S. Census Bureau 2018).

We further subset the FBO sample frame to only include the 45 Florida counties that are most likely to be associated with GOM private boat fishing.[6] In this case, a county is "associated" with the GOM if at least 50% of the 2005–2017 average annual estimated fishing trips during November and December from the county were to the GOM from the WFL. We also define trips during this period as associated with Gag if the angler either targeted (primary or secondary) or caught (kept or released dead or alive) Gag in the GOM from the WFL. These 45 counties account for 96% of all GOM trips and 99% of all Gag trips in the GOM. Note that this sample frame will not cover the entire population of anglers who fish in the GOM from the WFL because, based on 18 years of Marine Recreational Information Program (MRIP) data, approximately 14% of anglers fishing from a private boat in the GOM from the WFL reside outside of Florida.

According to the FBO database, there were 77,223 vessels registered in the 45 counties of interest during the study period. We further narrowed the FBO frame from these counties to include only the 13,879 registrations that were for a fiberglass-hull power boat (inboard, outboard, or stern drive engine) at least 20 ft in length and designated for pleasure use. These vessels are the most likely to fish in the GOM. We sampled 7,267 vessel registrations from the FBO to obtain our target sample size based on an assumed Gag angler prevalence of 0.32 and response rates of 0.15 for the e-mail survey and 0.38 for the mail-push survey with the US$2 incentive.[7]

[4]This study does not include anglers fishing from for-hire or rental boats.

[5]The FBO list was obtained from the BoatOwners Database, maintained by Info-Link Technologies, Inc., and the FLSA list was obtained from the Office of Science and Technology (National Oceanic and Atmospheric Administration Fisheries).

[6]The list of the 45 Florida counties in the sample frame is presented in Appendix 1.

[7]The assumed response rates and prevalence of Gag anglers were based on a pilot study conducted in January 2019. More details on the pilot study and sampling assumptions are available upon request.

However, the sampling was done such that approximately 25% of the records *did not* have a match in the FLSA list to ensure that we had sufficient coverage of the population that can saltwater fish in Florida without a license.

The FBFS was a mixed-mode survey with two general sampling strategies. The first was an e-mail and Web survey strategy that made all contacts (invitations, reminders, etc.) via e-mail. In this strategy, 6,391 contacts from the FBO sample were instructed to click a link in the e-mail to take the survey online. The second sampling approach was a mail-push strategy that made all contacts via the mail and included a $2 incentive with the survey invitation letter. In the mail-push strategy, 876 contacts from the FBO sample were mailed a letter with instructions to use a URL and a unique identification code to complete the survey online. The mail-push strategy also sent a paper version of the survey to those who did not respond after a reminder postcard (Messer and Dillman 2011).[8]

There was a total of 1,443 complete surveys returned from the 7,268 surveys delivered to valid addresses (e-mail or mail), giving a response rate of 20% for the combined mail-push and e-mail contact surveys. This response rate is consistent with other angler surveys employing a similar sampling strategy (Wallen et al. 2016). The final disposition of the original sample of the 7,267 contacts is shown in Figure 1. We did not know in advance the actual proportion of the target population that would occur in each of these sample segments. The numbers in parentheses (Figure 1) represent the proportion of the entire sample in each segment. Based on the figure, nearly two-thirds of the sample used their boats during November or December of 2019 and roughly half of the sample used their boats to fish in the GOM. More importantly, for our purposes, about one-quarter of the sample stated that they "fished for Gag Grouper" in the GOM during the same period.

Survey questions.— There were two main sections of the survey following a question confirming boat ownership and questions regarding the type of boat usage during November and December of 2019. For the respondents that used their boats for fishing, the first section asks a series of questions related to fishing activity during November and December of 2019. Specifically, respondents were asked to report the number of trips taken in November and December of 2019 and the total cost paid by all anglers on a typical trip. We also asked for the duration of a typical trip and the number of anglers on board a typical trip.

[8]We show in a companion paper (D. W. Carter and S. Lovell, unpublished data) that the two sampling strategies produced similar estimates, so we were able to pool the data for the purposes of this paper. For reference, the response rates of the e-mail and mail-push/incentive contact strategies were 0.18 and 0.41, respectively.

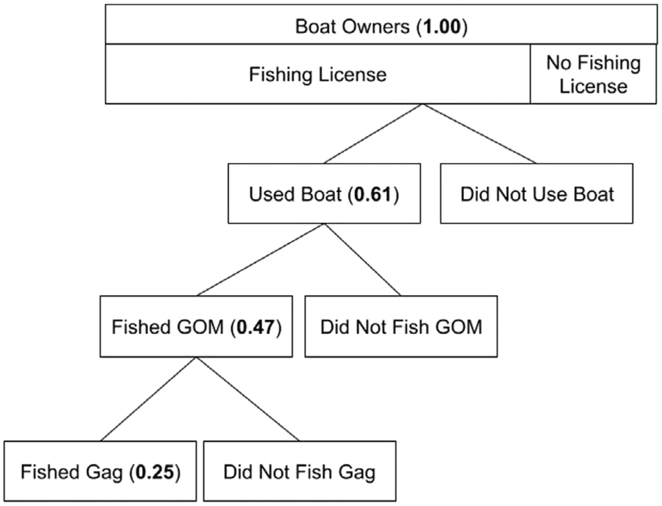

FIGURE 1. Florida Boating and Fishing Survey sample segments (GOM = Gulf of Mexico).

The second section of the survey contained two types of CB questions that asked respondents to report the number of trips they would have taken in November and December of 2019 if fishing costs or Gag regulations had been different. This is a type of "reassessed CB" trip question format that asks anglers to reassess how many trips they would have taken if hypothetical trip costs or Gag regulations had been in place (Simoes et al. 2013). The full set of CB question scenarios is summarized in Table 1, where the first row represents actual conditions in November and December 2019, the second two rows represent the cost (price) scenarios, and the last three rows represent the Gag bag limit scenarios. There are two sources of variation in the scenarios when collected for a set of anglers: (1) across anglers and (2) across scenarios within one angler.

The first CB question in the survey (row 2 of Table 1) asked for the number of trips that would have been taken if the cost had been double the cost of a typical trip, and the second CB cost question (row 3) asked for the number of trips if the cost had been half that of a typical trip. According to the law of demand for normal goods, the number of trips taken when trip cost doubles should be lower than the number of trips taken in the base scenario. The opposite should be true when the trip cost is cut in half.

TABLE 1. Trip scenarios. The first column shows the scenario label and the last three columns show the trip cost/price, number of trips, and bag limit data recorded for each survey respondent. The letters in parentheses correspond with the symbols in equation (1); the subscripts indicate the scenario, with zero denoting the information associated with the angler's actual trip.

Scenario	Price (p)	Trips (d)	Bag (r)
Base (actual)	p_0	d_0	2
Double price	$p_1 = p_0 \times 2$	d_1	2
Half price	$p_2 = p_0/2$	d_2	2
Bag = 3	p_0	d_3	3
Bag = 1	p_0	d_4	1
Bag = 0 (closed)	p_0	d_5	0

The other three CB questions (rows 4–6) asked for the number of trips that would have been taken if the bag limit had been three fish, one fish, or zero fish (closed season). These questions were only shown to those who reported fishing for Gag during November or December of 2019 and stated that they might have taken a different number of trips if Gag regulations had been different. Note that the hypothetical regulation questions asked the angler to consider changes in the number of *all* trips, not just those trips that targeted Gag.[9] For the analysis, we set the trips in the Gag regulation scenarios to the actual trips for those who stated that they would not have changed their trips under different Gag regulations. Checking the consistency of the bag limit scenarios is more complicated because there is no clear theory regarding the direction of change in the number of trips in response to bag limit changes (Woodward and Griffin 2003). If, however, we assume that more fish are preferred to fewer fish and that there is no reasonable limit on the number of fish that anglers want during the study period, then we would expect more trips to be taken at higher bag limits and fewer trips to be taken at lower bag limits and when the season is closed to Gag fishing.

Trip demand model.— Following Alberini et al. (2007), we use a single-site travel cost model of recreational fishing in the GOM under the alternative trip cost and fishing regulation scenarios shown in Table 1. We assume that an angler i chooses the number of fishing trips, d_{ij}, and a numeraire good, X_{ij}, under scenario j that maximizes utility subject to a budget constraint and fishing quality, h_{ij}, per trip, or $\max_{X_{ij}, d_{ij}} U(X_{ij}, d_{ij}) | y_i = X_{ij} + d_{ij} \cdot p_{ij}$ and $h_{ij} = f(s, k_i, r_{ij})$, where p_{ij} is the cost per fishing trip in scenario j for angler i, y_i is angler income, and the price of the numeraire good is set to 1. We further assume that fishing quality is a function of the fish stock, s_i angler skill, k_i; and fishing regulations, r_{ij}. Note that angler income and skill do not vary by scenario and that fish stock does not vary by angler or scenario. Furthermore, we assume that fishing trips and fishing quality are weak complements such that $\partial U/\partial h = 0$ if $d = 0$ (i.e., the individual does not care about the quality of fishing if he or she does not fish).

[9]The Gag is part of a bottom-fish complex that includes many substitute species. We assume that the respondents considered these alternative targets when reporting the number of trips that they would have taken under the hypothetical Gag regulation scenarios. We return to this point in the Discussion section.

The solution to the angler problem yields the demand function for trips, $d_{ij} = d\left(s, y_i, k_i, p_{ij}, r_{ij}\right)$. In our empirical work, we assume that the trip demand data follow a Poisson distribution and we estimate the following fixed-effect trip demand model:

$$d_{ij} = \exp\left(\alpha_i + \gamma p_{ij} + \delta r_{ij} + \lambda r_{ij}^2 + \theta h_{ij} + \phi h_{ij} p_{ij}\right), \quad (1)$$

where α_i is an angler-specificfixed effect, γ is the trip cost parameter, and δ and λ are the regulation parameters. We include an indicator, h_{ij}, for the hypothetical scenarios and interact the indicator with the cost variable.[10] The parameters on the hypothetical indicator, θ and ϕ, are meant to capture the differences in the unmodeled factors that affect trips reported in the hypothetical scenarios (Englin and Cameron 1996; Haab et al. 2012a, 2012b). For example, the hypothetical indicator could measure errors on the part of the respondent. The Internet survey reminded the respondent how many trips he or she took in the base case before each hypothetical scenario question. However, respondents could have made an error (e.g., recording or recall) such that the expected trips over the hypothetical scenarios at the baseline cost and bag limit do not equal the actual trips. The parameters associated with the dummy variable designating the hypothetical scenarios should capture this error.

With the Poisson fixed-effects estimator, the unobserved factors represented by the fixed effects can be correlated with p, r, or h without biasing the corresponding parameters. This is important because the angler response to changes in trip costs and bag limits is likely to be related to angler characteristics or fish stock conditions that are not included in the model.[11]

Note that the independent variables (e.g., fish stock, income, and skill) that do not vary by scenario cannot be separately identified in this specification because these factors are perfectly correlated with the angler-specific fixed effect. Therefore, with this estimator we cannot directly estimate the effect of different fish stock, income, or skill levels on angler demand for trips. Income can be an important influence on trip demand, and an explicit income parameter is necessary to estimate *exact* measures for the value of a fishing trip and the value of changes in the Gag bag limit. In Appendix 2, we use an alternative procedure to estimate the income parameter for this model and show that it is relatively small such that there is very little difference between the value of a fishing trip including income effects and the value of a trip without income effects that we report in the main text.

The main objective of this work is to understand how the number of trips and the value of fishing change when there are changes in trip costs or Gag regulations. We can use equation (1) to predict the expected number of trips per angler for any given combination of trip cost and Gag bag limit. Another way to calculate the change in trips expected with a change in trip cost or bag limit is with semi-elasticities, which measure the percent change in trips expected with a unit change in trip cost or bag limit, all else being equal. The trip cost semi-elasticity is simply the parameter γ on this variable. The semi-elasticity for the bag limit is slightly more complicated because there is a square term: $\delta r_{ij} + 2\lambda r_{ij}$. The trip cost and bag limit semi-elasticities are especially useful for measuring the potential change in recreational fishing trips anticipated with changes in fishing costs or regulations when the total number of trips is known, but there is no information available on the number of anglers.

Another useful expression for the purposes of evaluating the effect of bag limit changes in aggregate is the ratio of the number of trips after a bag limit change to the number of trips before a bag limit change:

$$\frac{D_1}{D_0} = \frac{\sum_{i=1}^{N} d_{i1}}{\sum_{i=1}^{N} d_{i0}} = \exp\{(r_1 - r_0) \times [\delta + \lambda(r_1 + r_0)]\}, \quad (2)$$

where D_j is the aggregate number of trips in scenario j, which for the purposes of this expression we denote $j = 0$ for the base scenario and $j = 1$ for the proposed scenario. If we assume that the total number of anglers, N, does not change, then we get the second line based on our trip demand specification. The assumption that the total number of anglers does not change when a regulation is changed is a common assumption in applied policy analysis. Equation (2) can be applied to the base number of aggregate trips to calculate the aggregate number of trips expected with a proposed change in the bag limit.

We can use economic theory and the estimated parameters of the trip demand equation to calculate the value of a fishing trip and the change in value per period that would be expected with a change in trip cost or the Gag bag limit (Haab and McConnell 2002). The negative of the inverse of the trip cost parameter gives the expected value of a fishing trip: that is, $CS = -1/\gamma$.[12] Here, CS

[10]We cannot interact the hypothetical indicator with the bag limit variables because the bag limit is fixed at two Gag for all anglers in the base case.

[11]The fixed-effect Poisson estimator has been frequently used in contingent behavior studies (e.g., Englin and Cameron 1996; Whitehead et al. 2011) because it is fully robust even if trips do not follow a Poisson distribution or if trips reported by the same angler are correlated (Wooldridge 2010). An alternative assumption would be a random-effects specification whereby α_i is unobserved but *assumed to be* uncorrelated with trip cost and the bag limit (e.g., Rosenberger and Loomis 1999; Whitehead et al. 2000; Alberini et al. 2007).

[12]The value per trip, including the effects of the hypothetical scenarios, would include the parameter on the interaction of the hypothetical indicator and trip cost: i.e., $CS = -1/(\gamma + \phi)$. We focus on the CS estimate without the effects of the hypothetical scenarios.

TABLE 2. Summary statistics for key variables (with SE in parentheses). Asterisks indicate a significant difference (***$P < 0.001$; **$P < 0.01$; *$P < 0.05$) between the means for anglers who targeted Gag and anglers who did not.

Variable	Targeted Gag? Yes	No	All
Actual fishing during Nov–Dec 2019			
Number of fishing trips	6.01 (0.31)	5.38 (0.29)	5.46 (0.26)
Total cost ($) of a typical trip	215.70 (10.05)	148.97 (9.73)***	157.87 (8.54)
Number of people on a typical trip	3.03 (0.06)	2.81 (0.06)*	2.84 (0.06)
Dock-to-dock hours of a typical trip	6.99 (0.11)	6.01 (0.11)***	6.14 (0.10)
Income			
2019 household income (× $10,000) before taxes	15.05 (0.49)	14.27 (0.49)	14.38 (0.43)
Trips during Nov–Dec 2019 with cost changes			
Double the cost	3.20 (0.20)	3.12 (0.22)	3.13 (0.20)
Half the cost	8.55 (0.41)	7.28 (0.40)*	7.44 (0.35)
Trips during Nov–Dec 2019 with Gag bag limit changes			
Three-fish bag limit	6.17 (0.34)		
One-fish bag limit	4.55 (0.24)		
Zero-fish bag limit (closed season)	4.09 (0.27)		
Number of observations	350	320	670

stands for consumer surplus, or the amount of money that anglers would be willing to pay, on average, for a day of fishing above and beyond the amount they actual pay for a typical fishing trip. The CS in our specification approximates the average amount of money that could be paid to an angler on any given day to make him or her indifferent to fishing. If we multiply the value of a fishing trip by the expected number of trips, we then get the value of fishing over a 2-month period for scenario j for angler i, or $\mathrm{CS}_{ij} = -d_{ij}/\gamma$. Similarly, we can calculate the change in 2-month fishing value for a change from scenario 0 to scenario 1 as $\mathrm{CS}_{i1}-\mathrm{CS}_{i0} = -(d_{i1}-d_{i0})/\gamma$. If, for example, we set the bag limit in scenario 0 to two fish and the bag limit in scenario 1 to three fish, then the change in CS measures the value of having the option to keep one additional fish on each trip over the 2-month period.

RESULTS

Data Summary

The summary statistics for the survey are shown in Table 2. We only show the results for respondents who used their boats for fishing. The remaining respondents either did not fish from their boats during November or December of 2019 or did not use their boats at all during this period. We show the results broken down by Gag targeting and overall. Note that the Gag anglers are overrepresented in our sample: approximately 52% of respondents in our sample indicated that they targeted Gag in November or December 2019, whereas according to the MRIP, only about 13% of angler trips targeted Gag during the same period. Therefore, the results in the last column of the table are weighted means and SEs.

In Table 2, the asterisks in the column for those who did not target Gag indicate the results of a t-test of the hypothesis that the means are equal between the Gag targeter subsample and the subsample of other anglers.[13] The average number of days fished is not statistically different between the Gag targeters and other anglers, but there are statistical differences in the means of the trip characteristics. In particular, the mean cost of a typical trip is more than 40% higher for Gag targeters than for the sample as a whole. This could be because Gag targeters take more people and are out on the boat about 1 h longer, on average, than other anglers.

The anglers in our sample have a relatively high household income, but there is not a significant difference in the income between those who targeted Gag and those who did not. On average, the number of days that anglers would have fished at double the typical cost was relatively lower and the number of days at half the actual cost was relatively higher, suggesting that the results are consistent with the law of demand. The response to halving the cost was statistically different between those who targeted Gag and those who did not, whereby Gag targeters were relatively more responsive to price decreases.

The actual bag limit during November and December of 2019 was two Gag. For those who targeted Gag, the

[13]Specifically, we tested the null hypothesis that the difference in means between the 350 Gag targeters and the remaining 320 anglers was different from zero.

TABLE 3. Poisson fixed-effect trip demand regression. The standard errors of the estimates are in parentheses. The asterisks indicate the P-value for statistical significance: ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$. CS is an abbreviation for consumer surplus.

		Targeted Gag?		
Variable	Parameter	Yes	No	All
		Trip demand model parameters		
Trip cost per angler (1/10)	γ	−0.055 (0.006)***	−0.046 (0.017)**	−0.047 (0.014)***
Hypothetical	θ	0.011 (0.037)	0.040 (0.036)	0.046 (0.030)
Trip cost (1/10) × hypothetical	ϕ	−0.006 (0.005)	−0.001 (0.001)	−0.001 (0.001)
Bag limit	δ	0.265 (0.046)***		
(Bag limit)^2	λ	−0.036 (0.011)**		
		Calculated parameters		
Semi-elasticity:zero-fish bag	$\delta + 2\lambda_0$	0.265 (0.046)***		
Semi-elasticity:one-fish bag	$\delta + 2\lambda_1$	0.192 (0.026)***		
Semi-elasticity:two-fish bag	$\delta + 2\lambda_2$	0.119 (0.017)***		
Semi-elasticity:three-fish bag	$\delta + 2\lambda_3$	0.046 (0.031)***		
CS per trip (actual)	$-1/\gamma$	181.559 (20.906)***	216.666 (77.456)**	210.791 (60.172)***
CS per trip (hypothetical)	$-1/(\gamma + \phi)$	162.599 (17.157)***	180.784 (69.101)**	175.379 (51.870)***
Log likelihood		−4,410.273	−1,970.853	−712,190.396
Number of observations		2,100	960	2,010

average stated number of trips was relatively higher with the three-fish bag limit and lower with the one-fish bag limit and the zero-fish bag limit (closed season). These results are consistent with the hypothesis that trip quality is positively related to the Gag bag limit and that anglers take more (or fewer) trips as the quality of each trip increases (decreases).

Trip Demand

The estimated parameters of the trip demand regressions are shown in Table 3 for all anglers and broken down by Gag targeting. The results for those who targeted Gag use all six trip observations shown in Table 1 for each angler, and the results for other anglers and for the combined sample only use the first three scenarios in Table 1. We use cluster-robust SEs to adjust for the fact that multiple observations from the same individual are likely to be correlated. These adjusted SEs account for both overdispersion and correlation over choices for a given angler (Bergé 2018). Additionally, the results for the combined sample (last column of Table 3) use weights that adjust for the oversampling of anglers who targeted Gag.

There are two trip cost parameters in each model: one on the trip cost and another on the interaction of trip cost with the hypothetical scenario indicator.[14] The trip cost parameter alone, γ, indicates the general response to changes in trip costs. Adding the parameter on the interaction variable gives the response to trip costs, including the effects inherent in the hypothetical scenarios. However, the hypothetical trip cost interaction parameter, ϕ, is not significantly different from zero in any of the models.

The trip cost parameters, γ, are similar between the Gag targeters and others.[15] Recalling that these parameters represent the percent change in trips with a unit change in trip cost, a \$10 change in trip costs would induce a 4.74% change in trips for the average angler and a 5.51% change in trips for the average angler who targeted Gag. The relationship between the number of trips for the average angler expected at different trip cost levels is shown in Figure 2 for all anglers and according to Gag targeting. The predictions in the graph fix the bag limit at two fish and set the "hypothetical" variable to zero. The graphs indicate the downward-sloping demand curves for boat fishing trips.

The trip response of anglers to bag limit changes is formally measured in Table 3 as bag limit semi-elasticities. We use the semi-elasticity expressions for the bag limit change presented earlier to calculate the bag limit semi-elasticity starting from zero, one, two, and three fish. The coefficients on the bag limit suggest that a one-fish change in the bag limit (from the current two-fish bag) is associated with a 11.92% change in the number of days fished by Gag targeters. This relationship is visualized for Gag targeters in Figure 3, which shows how the trip demand curve shifts with the bag limit changes. The figure uses the

[14] Note that we divided the typical cost by the typical number of people to obtain cost on a per-person basis. This does not scale the regression results because any factor that does not vary by scenario (e.g., typical cost and people per trip) is not separately identified in the fixed-effects estimator.

[15] For the purposes of the trip demand response discussion, we focus on the trip cost parameter γ that does not include the effects of the hypothetical scenarios.

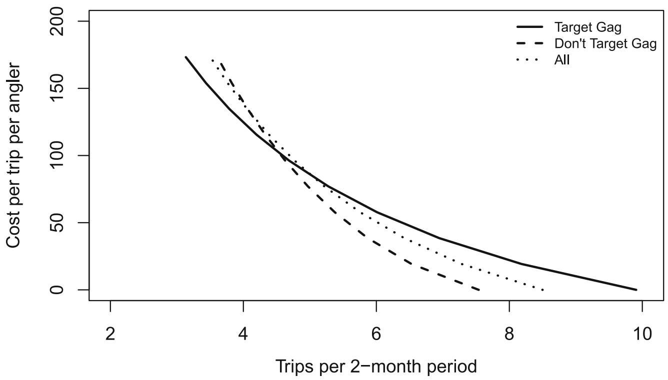

FIGURE 2. Trips as a function of cost ($) with a two-Gag bag limit.

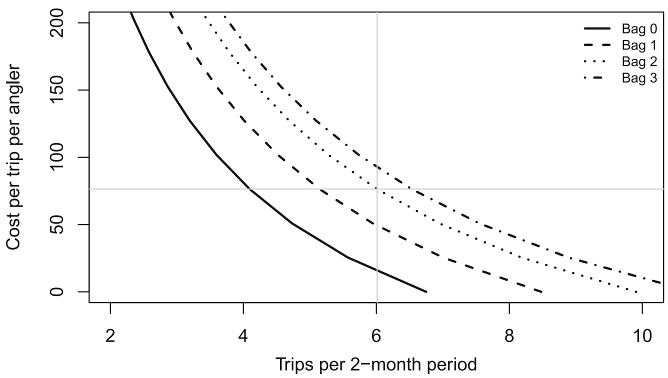

FIGURE 3. Trips as a function of cost ($) with different bag limits for Gag targeters.

estimated parameters in Table 3 and the trip demand equation (equation 1) to predict and plot the expected number of trips per angler. For reference, we show horizontal and vertical lines at the current bag limit (two fish) and mean number of trips, respectively. The graphs show how the curves shift when the bag limit changes: higher bag limits are associated with outward (from the origin) shifts in the trip demand curve.

The last two parameters reported in Table 3 are based on the negative of the inverse of the trip cost parameters, which measures the CS per trip for the average angler. The first CS estimate (actual) is based only on the trip cost parameter, γ, whereas the second CS estimate (hypothetical) adds the effect of the trip cost interaction with the hypothetical scenario indicator. The second CS estimate captures the effect of the hypothetical scenarios, which, as noted above, contain relatively more options that suggest trip decreases rather than trip increases. Therefore, the CS-per-trip measures that include the effects of the hypothetical choices are relatively lower. Focusing on the first CS estimates based on the main trip cost parameter, the average CS per trip for the anglers who targeted Gag is lower than the average CS for the anglers who did not. Multiplying these CS estimates by the average number of trips taken in November and December of 2019 gives the total CS from fishing for the average angler of $1,091 for Gag targeters, $1,165 for other anglers, and $1,151 over all anglers.

TABLE 4. Expected trips over 2 months and related consumer surplus (CS) with different bag limits for Gag. The results for the current two-fish bag limit are denoted in bold italics.

Bag	Trips	Change in trips	CS ($)	Change in CS ($)
Zero fish	4.09	NA	743	NA
One fish	5.15	1.05	934	191
Two fish	***6.01***	***0.87***	***1,091***	***157***
Three fish	6.53	0.52	1,186	94
Four fish	6.60	0.07	1,198	12

Table 4 shows the mean predicted trips and estimated CS for bag limits of up to four fish for Gag targeters. The column labeled "Trips" contains the predicted trips that are graphed in Figure 3 as the trips for which the base trip cost (horizontal line) intersects each demand curve. The incremental trips are shown in the column labeled "Change in trips." The "CS" and "Change in CS" columns are simply the trips or change in trips multiplied by the relevant (actual) CS-per-trip estimate from Table 3 ($181.56). Based on the results in Table 4 for the current two-fish bag limit, the average angler who targets Gag is willing to pay about $1,000 more than it actually costs them to fish during a 2-month period. Furthermore, the expected change in CS with each bag limit increment is decreasing. Note that we include the predicted trips and CS results for a four-fish bag limit, which is beyond the range of the scenarios shown to survey respondents. The prediction of trips expected with bag limits outside the range of those included in the study is possible using in the estimated demand equation (equation 1). However, we caution against extrapolating too far from the original range of zero to three fish used in the experiment.

DISCUSSION

We estimated a recreational fishing trip demand model using actual behavior and CB data on Florida anglers fishing from boats in the GOM. The parameters of the model were used to calculate the potential response of anglers to changes in fishing costs and bag limits for Gag. Our results suggest that boat anglers take about 5% fewer trips for every $10 increase in trip costs. Similarly, on average, anglers are predicted to take approximately 12% more trips when the Gag bag limit is increased by one fish. We show that the change in the number of trips expected with each bag limit increases at a decreasing rate.

The model results indicate that the average CS per trip per angler is about \$211, which, conceptually, corresponds to the amount of money that an angler is willing to pay above the amount they actually pay for each fishing trip. Our CS estimate is slightly higher than the average estimate for similar activities in the literature. For example, the mean CS per day of saltwater fishing in the southern USA is \$135 based on 56 estimates in the Recreation Use Values Database (Rosenberger 2016).[16] However, our estimate of CS per trip is still within the range of other estimates in the literature.[17]

The mean CS per angler per trip times the mean number of trips for a 2-month period is around \$1,151 for the average angler and \$1,091 for the average angler who targeted Gag. On average, over a 2-month period, each bag limit increment appears to be worth anywhere between \$12 and \$191, depending on which increment is being considered. For example, the first Gag bag limit increment (i.e., opening the season) increases the average 2-month value per angler by around \$191, whereas the third increment only increases the 2-month value by about \$94.

Our results can be used to estimate the economic effects of proposed changes in bag limit policies, including seasonal closures. We offer two examples of how to apply the results, which we hope will be helpful to those interested in Gag policy analysis. First, imagine a proposal to increase the Gag bag limit from two to three fish in federal waters of the GOM during November and December. According to the MRIP, there were 0.25 million private boat angler trips that targeted or caught Gag in the GOM from Florida during November and December of 2019. Based on the results in Table 3, the percent change in trips anticipated when the bag limit is increased from two to three fish is 11.92%. Multiplying this percent change by the estimated number of trips gives a change of 0.03 million trips. We can then multiply this change in trips by the estimated value (CS) per trip of \$181.56 to obtain the total change in value anticipated with the increase in the bag limit: \$5.51 million. A 95% confidence interval of \$3.64–7.38 million for this estimate of the expected change in aggregate angler value with the increase in the bag limit is calculated by applying the delta method to the following expression: $-0.25 \cdot (\delta + 2 \cdot 2 \cdot \lambda)/\gamma$.

However, there is also uncertainty in the MRIP point estimate of the total number of private boat angler trips that targeted Gag. The SE of the MRIP estimate is relatively large (0.1) such that the confidence interval becomes −\$67.27 to \$78.29 million when we incorporate this source of uncertainty. More precise MRIP estimates would help to narrow down the estimates of change in economic value associated with bag limit changes. Future work could also explore the use of alternative sources of recreational fishing effort estimates in the area, such as the Florida State Reef Fish Survey (SRFS).[18]

For our second example, consider a policy that would close Gag fishing during the last 2 months of the year. As noted above, the Gag season currently runs from June through December. In this case, we will use the trip change ratio formula presented in equation (2), with the base bag limit at two fish and the proposed bag limit at zero—but only for November and December. From the previous example, there were 0.25 million private boat angler trips that targeted Gag in the GOM from Florida during November and December of 2019. Evaluating equation (2) with the current and proposed bag limits yields an estimate of 0.68 for the ratio of trips conditional on the proposed bag limit to the trips conditional on the existing bag limit. Multiplying this ratio by the base number of trips gives the new trip estimate of 0.17 million. Multiplying the change in trips by the CS per trip gives the loss in economic value to private boat fishing expected with the proposed policy: \$14.73 million. As in the previous example, we can use the delta method to calculate the confidence interval of the expected change in value as \$10.25–19.22 million.[19] Again, though, this confidence interval becomes much wider (−\$180.32 to \$209.79 million) when we include the uncertainty associated with the MRIP trip estimate.

There are a few caveats to our study that point to directions for further research. First, the variation used to identify the relationship between bag limits and the number of trips is based entirely on stated preferences because the bag limit was the same for everyone during the study period. The stated responses may not accurately measure the effort changes that would occur if bag limits were actually changed. Future work would seek out cases where changes in regulations over space and/or time could be used to measure actual effort responses. These cases are very difficult to identify in marine fisheries where the regulations are typically applied over large geographic areas and change infrequently. Field experiments that purposely vary regulations to measure response could be one approach. An example from an inland fishery in Newfoundland measured effort

[16]The mean estimate from the Recreation Use Values Database is \$126.96 in 2016 dollars. We inflate to 2019 dollars using the consumer price index inflator.

[17]At the high end, Gillig et al. (2000) reported a CS per trip estimate for Red Snapper target trips of \$213 in 1991 dollars, which would be over \$400 in 2019 dollars.

[18]We recently repeated this study using the same sample frame and stratification scheme as the Florida SRFS. The parameter estimates are similar to those reported in this study, and we are working on ways to generate aggregate estimates of trip changes and economic value using the Florida SRFS procedures.

[19]Based on equation (2) and the expression for CS per trip, the formula for the delta method in this case is $-0.25 \cdot [1-\exp\{(0-2) \cdot [\delta + \lambda \cdot (0+2)]\}]/\gamma$.

changes in response to experimentally varied management regimes (Veinott et al. 2018).

Another caveat to our study relates to sources of uncertainty in the analysis and results. We showed in the above examples how uncertainty can be incorporated into calculation of expected changes in value associated with changes in regulations. However, this uncertainty is conditional on the data and model selected for estimation. In particular, as noted in the previous caveat, we cannot be certain that the number of trips anglers stated under the hypothetical bag limit scenarios is the same number of trips that they would take if they actually faced these scenarios. The literature comparing actual and hypothetical (contingent) demand responses to policy changes is mixed but generally reports that, on average, responses to hypothetical scenarios are relatively higher than actual responses to the same scenarios.[20] Again, a different type of experimental or quasi-experimental analysis would be necessary to evaluate this uncertainty in our study context.

Our study focused on effort responses during a 2-month period. Gag are open to fishing in our study area from June to December. Whether we can extrapolate the results to other months remains to be seen. Additional survey work at other times of the year would be necessary to determine whether the effort response and economic value per trip that we measured for trips during November and December can be applied to regulation changes during other times of the year.

Lastly, there other factors not included in the model that could influence angler behavior, such as angler perceptions of stock health or potential benefits of engaging in an alternative fishery. While our statistical (fixed-effects) modeling controlled for these factors, information about which angler characteristics and perceptions are most important in determining the response of effort to regulation change could be helpful to fishery managers. Future work could aim to identify the sources of variation in angler trip-taking behavior, perhaps expanding on the work of Murphy et al. (2019). Furthermore, as one reviewer suggested, "It would be particularly instructive to survey a fishery before regulations were changed to get angler perceptions, and then after regulations changed to see whether the model predictions were accurate." As far as we know, this has never been done but would make an interesting extension to our work.

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[20]Hoyos and Riera (2013) found that actual and hypothetical estimates diverged for five out of the eight relevant studies that they reviewed and the case study they evaluated.

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Appendix 1: Sample Frame Counties

TABLE A.1.1. Florida counties that were included in the survey sample frame.

County		
Alachua	Hamilton	Marion
Bay	Hardee	Monroe
Bradford	Hendry	Okaloosa
Calhoun	Hernando	Pasco
Charlotte	Highlands	Pinellas
Citrus	Hillsborough	Polk
Collier	Jackson	Santa Rosa
Columbia	Jefferson	Sarasota
Desoto	Lafayette	Sumter
Dixie	Lake	Suwannee
Escambia	Lee	Taylor
Franklin	Leon	Union
Gadsden	Levy	Wakulla
Gilchrist	Madison	Walton
Gulf	Manatee	Washington

Appendix 2: Income Effects in the Trip Demand Model

We can modify equation (1) to incorporate income as follows:

$$d_{ij} = \exp\left(\ln\alpha_i + \gamma p_{ij} + \delta r_{ij} + \lambda r_{ij}^2 + \theta h_{ij} + \zeta w_i\right), \quad \text{A.1}$$

where w_i is the 2-month household income of angler i. Note that the income parameter, ζ, is not identified in the fixed-effect Poisson model because income is does not vary by scenario and is, therefore, perfectly correlated with the fixed effects, α_i. However, we can use an auxiliary, second-stage equation to explain the variation in the angler-specificfixed effects with the variation in income (Honoré and Kesina 2017):

$$\alpha_i = \exp(\eta + \zeta w_i), \quad \text{A.2}$$

where η is an intercept. The income parameter, ζ, identified with this auxiliary equation can be used to calculate the *exact* compensating variation (CV) welfare measure based on the consumer surplus (CS) measures as follows (Alston and Larson 1993):

$$\text{CV} = \log_e(1 + \zeta \cdot \text{CS})/\zeta. \quad \text{A.3}$$

The SEs of the income effect and related CV welfare effects are estimated using a cluster bootstrap procedure (Cheng et al. 2013; Cameron and Miller 2015). To implement the bootstrap for parameters β, we proceed as follows: Sample anglers (respondents) with replacement N times from the original sample of anglers. For the sampled N anglers, retain all of the trips taken to form the first bootstrap sample. Obtain estimates, β_b, from the first sample. Repeat steps 1–3 B times to obtain B bootstrap estimates.

Finally, calculate the variance of the B bootstrap estimates to obtain the estimated variance:

$$V\left[\widehat{\beta}\right] = \frac{1}{(B-1)} \Sigma_{b=1}^{B} \left(\widehat{\beta}_b - \overline{\beta}\right)\left(\widehat{\beta}_b - \overline{\beta}\right)', \quad \text{A.4}$$

where $\overline{\beta} = B^{-1}\Sigma_{b=1}^{B}\widehat{\beta}_b$ and $B = 1{,}000$. Note that the resampling is done over anglers rather than over scenarios. In this way, some anglers may not appear in bootstrap samples at all, while other anglers will appear multiple times. The results of the estimation with income effects are shown in Table A.2.1. Note that we scaled income to be in thousands of U.S. dollars before estimation, but we rescaled the income parameter before calculating the CV estimate. The parameter on income is negative but very small. Negative income effects are common in recreational trip demand models, where, for example, higher income levels represent more money to spend on fishing trips but also a larger opportunity cost of work foregone when taking a fishing trip (Taylor et al. 2010). The small income coefficient is evident in the fact that there is very little difference between the CS and CV measures of the value per trip.

TABLE A.2.1. Two-stage trip demand regression with income for Gag targeters. The standard errors of the estimates are in parentheses. The asterisks indicate the P-value for statistical significance: ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$. CS is an abbreviation for consumer surplus and CV is an abbreviation for compensating variation.

	Parameter	First stage	Second stage
Trip demand model parameters			
Trip cost (1/10)	γ	−0.056 (0.006)***	
Bag limit	δ	0.265 (0.045)***	
(Bag limit)^2	λ	−0.037 (0.011)**	
Hypothetical	θ	0.008 (0.036)	
Trip cost (1/10) × hypothetical	ϕ	−0.006 (0.005)	
Intercept	η		1.750 (0.164)***
2-month income (thousands)	ζ		0.010 (0.008)
Calculated parameters			
CS per trip	$-1/\gamma$	180.479 (20.799)***	
CV per trip	$\log_e(1 + \zeta \cdot \text{CS})/\zeta$		180.325 (20.800)***
Number of observations		2,100	350