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IS THE 2012 ALLOCATION OF RED SNAPPER IN THE GULF OF MEXICO ECONOMICALLY EFFICIENT?

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JUAN J. AGAR AND DAVID W. CARTER

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
Miami Laboratory
75 Virginia Beach Drive
Miami, Florida 33149

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U. S. DEPARTMENT OF COMMERCE
Penny Pritzker, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Kathryn D. Sullivan, Under Secretary for Oceans and Atmosphere

NATIONAL MARINE FISHERIES SERVICE
Eileen Sobeck, Assistant Administrator for Fisheries

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NOTICE

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Copies may be obtained by writing:
David W. Carter
NOAA Fisheries
75 Virginia Beach Drive
Miami, Florida 33149
David.W.Carter@noaa.gov

National Technical Information Center
5825 Port Royal Road
Springfield, VA 22161
(800) 553-6847 or
(703) 605- 6000
http://www.ntis.gov/numbers.htm

Is the 2012 allocation of red snapper in the Gulf of Mexico economically efficient?

Abstract

This report investigates the economic efficiency of the current allocation of red snapper between the commercial and recreational fishing sectors in the Gulf of Mexico. Our results suggest that the 2012 allocations are not economically efficient because the net benefit for an additional unit of quota at the margin differs between these sectors. However, the magnitude of the reallocation and the extent to which national economic benefits can be increased can only be confidently determined with additional research, improvements in the quality of existing data collections and new data collections.

Note

This document was originally distributed in 2012 in support of the Red Snapper Allocation Options Paper for Amendment 28 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico

Contents

1. Introduction

Fishery management bodies concerned with managing resources for greatest overall benefit to the nation require information on benefits derived from food production and recreational opportunities. The fundamental principle of economic efficiency requires that net benefits of the existing quota allocation must be equal at the margin. If they are not equal, then the nation is not maximizing the economic benefits from these scarce resources. In other words, the economic well-being of the nation can be improved by shifting quota from the sector with the lower net benefit to the sector with the higher net benefit for that last unit of quota. Perusal of the economic literature on the issue of resource allocation shows that most studies dealing with this issue are theoretical (see, McConnell and Sutinen, 1979; Bishop and Samples, 1980; Edwards, 1990; Edwards, 1991); there are few empirical applications (Campbell and Nichol, 1995; Carter et al., 2008; Gentner et al., 2010; Agar and Carter 2014).

The objective of this report is to assess the economic efficiency of the 2012 commercial recreational allocation for the Gulf of Mexico red snapper fishery by considering each sector's willingness to pay for an additional unit of quota. However, we do not attempt to calculate the economically efficient allocation nor measure the potential economic benefits of reallocation. The methods we use follow earlier work with grouper species in the Gulf of Mexico (Agar and Carter 2014; Carter et al. 2008).

The remainder of the report is structured as follows. Section 2 provides a brief overview of the commercial fishery and describes the calculation of the net benefit for the next pound of fish to the commercial sector. Section 3 provides some background on the recreational fishery and describes the calculation of the net benefit for the next pound of fish to the recreational sector. The last section presents the main conclusions of this work.

2. Commercial sector analysis

A. Recent management history

Red snapper (*Lutjanus campechanus*) is the dominant fishery species in the shallow-water snapper complex of the northern Gulf of Mexico. Red snapper stocks support important commercial and recreational fisheries. Vertical lines and, to a lesser extent, bottom longlines are the main commercial gears that prosecute this resource. In 2011, the commercial fleet landed 3.24 million pounds (gutted weight) valued at $ 11.6 million (NMFS, 2012). Prior to 2007, the fishery was mainly managed using license limitations, trip limits (either 200 lbs. or 2,000 lbs.), harvest seasons and seasonal quotas, which led to declining stocks, overcapacity and derby fishing conditions, which in turn resulted in market gluts, depressed prices, higher harvesting costs, and unsafe fishing practices (Waters, 2001).

In January 2007, the Gulf of Mexico Fishery Management Council (GMFMC) sought to reverse this situation by implementing individual fishing quota (IFQ). Amendment 26 to the Reef Fish Fishery Management Plan (FMP) established a red snapper IFQ program to reduce overcapacity and to mitigate, to the extent possible, race to fish conditions. The IFQ program grants fishermen a share of the commercial quota which entitles them to harvest an annual allocation (i.e., given amount of fish in a year) without the need to outcompete other fishermen. Shares and allocation can be freely traded.[1] Although, the program is still being assessed the evidence points to significant savings in capital devoted to catching red snapper. Statistics from the coastal logbook

[1] There is a 6.0203% cap on the accumulation and transfer of IFQ shares; however, there is no cap on the amount of IFQ allocation that may be held and transferred during the calendar year.

program show that between 2006 and 2011, the number of vessels and fishing trips contracted 20% and 31%, respectively. Also, the fishing season transitioned from an average of 109 calendar days during the 5 years preceding the IFQ program to a year round fishery which afforded fishermen greater flexibility to meet market demands. The annual catch limits (ACLs) were reduced from 4.19 MP (gutted wt.) in 2006 to 2.3 MP (gutted wt.) starting in 2007. The ACLs began increasing again in 2010 following a stock assessment update which indicated that red snapper stocks were no longer undergoing overfishing (Table 1).

Table 1. Gulf of Mexico red snapper commercial quota.

Year	ACL at Beginning of the Year	Quota change	Date of quota change	ACL at End of the Year
2007	2,297,297	689,189	June 1	2,986,486
2008	2,297,297	N/A	N/A	2,297,297
2009	2,297,297	N/A	N/A	2,297,297
2010	2,297,297	893,694	June 2	3,190,991
2011	3,190,991	109,910	June 1	3,300,901
2012	3,712,613	-	-	-

Numbers are in pounds of gutted weight.

B. The Commercial Model

The research on calculating the net benefits of harvest allocations in commercial fisheries has employed either a general equilibrium or a partial equilibrium approach. General equilibrium approaches examine changes in supply, demand and prices in multiple interacting markets whereas partial equilibrium approaches examine the behavior of supply, demand and prices in a single market. For instance, Thurman and Easley (1992) used a general equilibrium approach to examine the change in economic value associated with restrictions (i.e. quotas) on the aggregate harvest of red drum. Their analysis used retail level data to model general equilibrium derived demand curves. In contrast, Carter et al. (2008) and Gentner et al. (2010) used a partial equilibrium approach to analyze an *ex-ante* potential redistribution of Gulf of Mexico red grouper and New England summer flounder quota, respectively. The choice of a partial over general equilibrium approach is usually due to a lack of retail level data. Carter et al (2008) and Gentner et al (2010) estimated derived demands for quota relationships from trip level data.

An alternative partial equilibrium approach to calculate the net benefits of aggregate harvest allocation decisions in the commercial sector uses information from ITQ markets. In well-behaved markets, the allocation (or "lease") price conveys the expected net benefit (i.e., profit) of harvesting an additional unit of quota (i.e., pound of allocation): a fisherman will only purchase an additional unit of allocation as long as the expected net benefit (i.e. profit) is greater than or equal to the allocation price (Clark 1990). With the exception of Agar and Carter (2012) we are not aware of empirical applications that have used IFQ allocation prices to determine the net benefit of commercial harvest for the economic analysis of fishery allocations.[2]

We follow the partial equilibrium approach in Agar and Carter (2012) to measure the net benefit of an additional unit of quota at the current allocation to the commercial sector. Specifically, we model the red snapper allocation price as a function of ACLs while controlling for dockside prices, factor costs (e. g., diesel 2), and amount of landings or quota leased (allocation):

$$p^{allocation} = f(p^{dockside}, \text{factor costs, landings, allocation, ACL}).$$

[2] There have been only a handful of studies examining the determinants of share and lease prices; however, not in the context of allocation (see Newell et al. 2005).

We expect that the allocation price, which captures the expected net of holding an additional unit of allocation, to be positively related to dockside prices and negatively related to harvesting costs. Also, we conjecture that the level of aggregate landings is a potential determinant of allocation purchases because information on aggregate landings is published regularly. Like Newell et al (2005) we use a reduced form approach to uncover the relationship between allocation prices and its determinants. However, our specifications are considerably more parsimonious given the limited number of observations available.

i. Data and specification

Data on allocation prices, allocation traded, landings, and dockside prices were obtained from the NMFS Southeast Regional Office (SERO) IFQ Database. Prices were adjusted by the consumer price index (2012=100). The consumer and diesel 2 price indices were obtained from the U.S. Bureau of Labor Statistics. The analysis focused on the 2007-2011 period when the IFQ program was in place. Nearly 80 percent of the allocation price observations were equal or less than one penny. Therefore, we created monthly averages using observations with values greater or equal $1 but less than $5.5, a realistic price range for arm's-length transactions. The average allocation price in 2007 was 1.80 $/lb.

Many dockside prices were reported net of the allocation price, rather than as the actual dockside price. Consequently, we created monthly dockside prices using observations with prices equal or greater than $2 and but less than $10. The average dockside price in 2007 was 3.54 $/lb. (NMFS, 2012). The descriptive statistics of the variables used in the analysis are found in Table 2.

Table 2. Descriptive statistics of the variables used in regression analysis.

Variable	Mean	Med.	Std. dev.	Min	Max
Red snapper monthly allocation price ($/lb.)	2.76	2.89	0.35	1.97	3.30
Red snapper monthly dockside price ($/lb.)	4.22	4.25	0.15	3.88	4.46
Diesel 2 price index	0.80	0.75	0.21	0.43	1.34
Red snapper monthly landings (MP GW)	0.23	0.22	0.08	0.09	0.51
Red snapper cumulative landings (MP GW)	1.52	1.58	0.78	0.1	3.24
Red snapper monthly allocation sold (MP GW)	0.04	0.03	0.05	0.01	0.37
Red snapper cumulative allocation sold (MP GW)	0.19	0.14	0.18	0.04	1.22
Red Snapper ACL (MP GW)	2.67	2.30	0.44	2.30	3.30

Source: NOAA IFQ Database, N=60, All prices are real (2012=100).
Allocation prices used in the analysis were limited to those greater than$ 1.00 and less or equal to $5.5.
Dockside prices used in the analysis were limited to those greater than $2.00 and less or equal to $10.
GW = gutted weight.

ii. Results

Table 3 shows the ordinary least squares (OLS) results of 8 different models that considered the relationship between red snapper allocation prices and dockside prices, diesel price index, monthly landings, cumulative monthly landings, monthly allocation traded, cumulative allocation traded, yearly and quarterly dichotomous variables, and annual catch limits (ACLs). In general, the results show that much of the variation in average allocation prices is across years rather than across quarters. Most of the explanatory variables such as dockside prices, diesel 2 index, monthly landings, cumulative monthly landings, monthly allocation traded and cumulative allocation traded are not statistically significant at the 5% level when yearly dummy variables are included

(Models 2, 4, 5, 6, 7, and 8). Only Model 4 yields an ACL parameter that is negative and statistically significant at the 5% level. Therefore we use Model 4 to predict the effect of changing ACLs on allocation prices while controlling for dockside price, diesel fuel prices and yearly fixed effects. The yearly fixed effect specification allows us to remove biases arising from omitted variables like fish abundance and price discovery that change from year to year. The predicted mean allocation price over a range of ACL levels is shown in Table 4 along with the lower (LCI) and upper (UCI) confidence estimates of the mean.

Table 3. Red snapper allocation price (marginal net benefit) regressions for the commercial fishing sector. Dependent Variable: Monthly allocation price (2012=100).

Independent Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Intercept	-4.93632*** (0.81584)	1.02008 (1.02707)	-4.93818*** (0.83042)	2.16144* (1.08770)	2.66876** (1.14020)	2.67129** (1.17501)	2.36460** (1.12281)	2.69201** (1.17341)
Monthly dockside price ($/lbs)	1.87956*** (0.19194)	0.33409 (0.24437)	1.88064*** (0.20358)	0.16447 (0.24379)	0.08453 (0.24867)	0.06489 (0.25864)	0.13431 (0.24779)	0.05451 (0.26018)
Diesel 2 index	-0.31525** (0.13747)	-0.15361 (0.15578)	-0.31455** (0.14448)	-0.12363 (0.14947)	-0.17693 (0.15322)	-0.17803 (0.15666)	-0.13084 (0.15033)	-0.18004 (0.15641)
Commercial ACL (MP)			-0.00130 (0.07510)	-0.17845** (0.07309)	-0.25560** (0.09173)	-0.19729** (0.07478)	-0.18888** (0.07459)	-0.19099** (0.07359)
Cumulative landings (MP)					0.04076 (0.02971)			
Cumulative allocation traded (MP)						-0.13573 (0.12018)		
Contemporaneous landings (MP)							-0.20328 (0.26188)	
Contemporaneous allocation traded (MP)								-0.47692 (0.40459)
Quarter 2 dummy	0.00176 (0.08136)		0.00179 (0.08214)					
Quarter 3 dummy	0.08241 (0.08090)		0.08279 (0.08454)					
Quarter 4 dummy	-0.01099 (0.07993)		-0.01059 (0.08387)					
Year 2008 dummy		0.26263*** (0.08637)		0.20751** (0.08562)	0.20845** (0.08491)	0.22612** (0.08697)	0.19909** (0.08663)	0.23429** (0.08827)
Year 2009 dummy		0.62723*** (0.07504)		0.59604*** (0.07289)	0.58006*** (0.07321)	0.59832*** (0.07272)	0.58625*** (0.07425)	0.60486*** (0.07300)
Year 2010 dummy		0.69893*** (0.09367)		0.77238*** (0.09448)	0.79985*** (0.09581)	0.82027*** (0.10334)	0.78599*** (0.09646)	0.81790*** (0.10175)
Year 2011 dummy		0.69298*** (0.12052)		0.84461*** (0.13091)	0.91688*** (0.14009)	0.92602*** (0.14914)	0.86916*** (0.13517)	0.92562*** (0.14742)
R Squared	0.6518	0.8594	0.6518	0.8738	0.8783	0.8769	0.8753	0.8772
Adjusted R Squared	0.6195	0.8434	0.6124	0.8568	0.8592	0.8576	0.8557	0.8579
F Value	20.21	53.98	16.53	51.45	46.02	45.41	44.75	45.53
Prob.> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Number of observations	60	60	60	60	60	60	60	60

***Statistically significant at 1%, ** statistically significant at 5%, *statistically significant at 10%. All weight units are in gutted weight.

Table 4. Predicted Mean Allocation Price as a Function of Different ACLs

ACL (MP)	Predicted Price ($/lb.)	LCI (95%)	UCI (95%)
3.30	3.01	2.74	3.29
3.35	3.01	2.73	3.28
3.40	3.00	2.72	3.28
3.50	2.98	2.70	3.26
3.53	2.97	2.69	3.26
3.56	2.97	2.69	3.25
3.60	2.96	2.68	3.24
3.64	2.95	2.67	3.24
3.68	2.95	2.66	3.23
3.71	2.94	2.65	3.23
3.75	2.93	2.65	3.22
3.79	2.93	2.64	3.22
3.82	2.92	2.63	3.21
3.86	2.91	2.62	3.21
3.90	2.91	2.61	3.20

3. Recreational Sector Analysis

This section describes the methods used to determine the net benefit for the next unit of recreational harvest at the current allocation of red snapper in the Gulf of Mexico. The net benefit of a pound of fish in the recreational sector is also referred to as the marginal willingness-to-pay (WTP). The marginal WTP for a pound of fish can be defined as either 1) the amount of money that would have to be *given to* an angler to make him indifferent to a *decrease* in a pound of fish or 2) the amount of money that would have to be *taken from* an angler to make him indifferent to an *increase* in a pound of fish. These two amounts are approximately equivalent for a one pound change in either direction. Note the similarity between the measure of net benefit per pound of fish in the recreational sector (i.e., marginal WTP) and the commercial sector (i.e., allocation price). Both measures represent the amount of money needed to make the person (angler or commercial fisherman) indifferent to getting an extra pound of fish.

A complete analysis of the marginal WTP at different recreational harvest allocations will account for the following three factors as well as the heterogeneity of anglers (Anderson, 1993; McConnell and Sutinen, 1979): the number of anglers, the number of trips per angler, and the number of fish harvested per angler per trip. In the two most recent allocation analysis for Gulf of Mexico fisheries we assumed that the first two factors did not change as allocations changed (Agar and Carter 2014; Carter et al., 2008). This is a reasonable assumption when measuring the marginal WTP for existing allocations or calculating the economic net benefits of relatively small allocation changes. We continue with this operating assumption in calculating the marginal WTP of the recreational sector at the current allocation of red snapper.[3]

[3] As in the two previous analyses, we also ignore dynamic feedbacks (e.g., congestion or stock effects) because this type of response is unlikely to be significant in the short-term when

In the Carter et al. (2008) analysis of red grouper allocations we assumed that the marginal WTP of fish harvested per angler per trip was constant over the number of fish harvested. The analysis was further limited because we did not have information on the distribution (heterogeneity) of WTP across anglers, i.e., we only had an estimate of the mean WTP. Both of these assumptions were relaxed in Agar and Carter (2012) using an analysis of data from a stated preference choice survey conducted in 2003 (Carter and Liese 2012, hereafter CL). We use the results of CL and follow the two approaches suggested in Agar and Carter (2012).

Following CL, the total WTP for red snapper per trip by angler *i* is given by

(1) $$WTP_i(h) = b_i \sinh^{-1} h$$

where b_i is a randomly distributed preference parameter for angler *i* and *h* is the red snapper harvest per angler per trip. This expression measures the amount of money you would have to take from angler *i* to make him indifferent to harvesting *h* fish per trip versus no fish per trip. In our first approach we use this expression to evaluate the marginal or *incremental* WTP for the average angler and set the value of *b* to the mean of the distribution, i.e., $b_1 = b_2 = \cdots = b_N = \bar{b}$. Following Agar and Carter (2012), we measure the marginal WTP of the current allocation in terms of the incremental WTP per trip starting from the current bag limit:

(2) $$MWTP_{bag} = \bar{b}[\sinh^{-1}(\lceil h \rceil + 1) - \sinh^{-1}\lceil h \rceil]$$

where $\lceil h \rceil$ is the current bag limit. This measure of the WTP for the next fish is converted to WTP per pound by dividing by the pounds per fish. There is more discussion of this approach below where we introduce the data and calculate the estimate.

considering marginal changes in harvest. We also assume that the distribution of trips, spatially and across the year, is also fixed.

The second approach to calculating the marginal WTP uses the equation estimated in CL in a slightly different way. Taking the derivative of the WTP equation (1) gives the marginal WTP or the inverse demand for harvest per trip for angler *i*

(3) $$p_i(h) = \frac{b_i}{\sqrt{1+h^2}}.$$

Note that the value of the *b* parameter indicates the WTP for a trip where no fish are harvested, i.e. where *h=0*. Inverting the function in (3) gives the *demand* for harvest per trip for each angler

(4) $$h_i(p) = \frac{\sqrt{(b_i - p)(b_i + p)}}{p}$$

where *p* is the price or cost per fish per angler per trip. In this expression, the *b* parameter approximates the choke price for harvest per trip. The aggregate recreational demand for red snapper harvest is the horizontal sum over all anglers and all trips

(5) $$H(p) = \bar{t}\sum_{i}^{N} \frac{\sqrt{(b_i - p)(b_i + p)}}{p}$$

where $\bar{t}$ is average number of trips by the *N* anglers in the "market" for red snapper. We create empirical version of the aggregate demand curve with corresponding price and harvest vectors, $(\vec{P}, \vec{H})$, and then read off the price or marginal WTP corresponding to the given allocation, i.e.

(6) $$MWTP_{demand} = \vec{P}[H_{allocation}]$$

where *P* is the vector of prices or marginal WTP corresponding to each possible harvest level and $H_{allocation}$ is the harvest allocation we are interested in evaluating. This measure of the WTP for the next fish is converted to WTP per pound by dividing by the pounds per fish.

Next we offer a brief history of red snapper regulations, targeting, and value per fish, followed by the two methods of estimating the marginal value of red snapper based on the 2012 recreational allocation in the Gulf of Mexico.

A. Red Snapper Harvest, Regulations, Targeted Trips, and the Value of Red Snapper Harvest per Trip

The historical recreational allocation, harvest, season length, bag limits, and minimum size limits for red snapper in the Gulf of Mexico are shown in Table 5. The number of days allowed for red snapper has decreased since 2007. The bag limit for red snapper was 4 fish prior to 2007 when it was decreased to 2 fish. Despite these efforts the harvest has been considerably over quota in four of the last five years with the exception being 2010 when the fishery was closed for the Deepwater Horizon (DWH) oil spill event. Furthermore, according to Table 6 the number and share of trips targeting red snapper has fluctuated around 300,000 trips or around 1% of all recreational fishing trips even as the regulations were tightened. The number of trips for red snapper increases by around 65,000 trips on average when the trips harvesting red snapper are included. As shown in the fifth column of Table 6, this expanded definition of red snapper trips comprises around 1.5% of all recreational trips in the Gulf of Mexico.

Table 5. Red Snapper Regulations and Harvest for the Recreational Fishery in the Gulf of Mexico

Year	Days Open	Minimum Size Limit (TL IN)	Bag Limit	Season Open	Season Closed	Quota (MP WW)	Harvest (MP WW)	% of Quota
2004	194	16	4	21-Apr	31-Oct	4.468	4.996	112%
2005							4.084	91%
2006							4.020	90%
2007	190		2	26-Apr	31-Oct	3.185	4.440	139%
2008	65			1-Jun	4-Aug	2.450	3.712	151%
2009	75			1-Jun	15-Aug	2.450	4.625	189%
2010	53			1-Jun	23-Jul	3.403	2.239	66%
2011	49			1-Jun	19-Jul	3.520	4.603	131%

WW = whole weight

Table 6. Recreational Fishing Trips in the Gulf of Mexico

Year	Red Snapper Target		Red Snapper Target or Harvest		Total Recreational Trips
	Number	Share of Total	Number	Share of Total	
2004	375,079	1.42%	480,524	1.82%	26,429,207
2005	226,253	0.97%	302,721	1.30%	23,289,807
2006	266,383	1.14%	360,439	1.55%	23,292,921
2007	387,461	1.60%	462,667	1.90%	24,289,264
2008	200,961	0.81%	273,283	1.10%	24,789,852
2009	312,738	1.38%	368,665	1.63%	22,597,249
2010	159,476	0.76%	186,771	0.89%	21,047,433
2011	299,747	1.33%	320,355	1.42%	22,575,779

Source: MRFSS. Does not include estimates from the Headboat Survey or the Texas Park and Wildlife Survey.

There are no estimates available of the number anglers, N, in the "market" for specific recreationally caught species in the Gulf of Mexico. Nor are there estimates of the average number of trips per year, $\bar{t}$, taken by these anglers. Table 7 shows how we calculated these quantities for each year from 2004 to 2011 for recreational fishing in the Gulf of Mexico. We divide the total number of Marine Recreational Fisheries Statistics (MRFSS) trips in the second column by the total number of participants in the third column to get the average number of trips per participant in the fourth column. The fifth column shows the estimated number trips that targeted or harvested red snapper, with the 95th confidence interval for this estimate in the sixth and seventh columns. These trips only include anglers interviewed as part of the MRFSS. The remaining red snapper harvest in the Gulf of Mexico is reported in the Head Boat Survey and the Texas Park and Wildlife Survey. The eighth column shows that the MRFSS typically accounts for around 80% of the annual recreational harvest of red snapper. Assuming that the number of trips is proportional to harvest we adjust the estimate of the total number of trips harvesting red snapper in the Gulf of Mexico by dividing the quantities in columns five through seven by the percentages in column eight. The result of this calculation is incorporated into the estimated number of anglers who target or harvest red snapper shown in the last three columns. The results in the last three columns are calculated by dividing the trip estimates in columns five through seven by the product of the trips per participant in column four and the harvest percent from the MRFSS in column eight. Though not shown in the table, the share of "red snapper" anglers as a proportion of the total participants in the Gulf of Mexico exhibits a downward trend similar trend in the target or harvest trips as a proportion of all trips reported in Table 6.

The CL study estimated equations for the WTP for grouper, red snapper, dolphinfish, and king mackerel harvested per angler per trip in the southeast U.S. All of these equations have the form of expression (1) with different estimates of *b* for each species. The incremental WTP curve for red snapper using equation (2) for the average angler in the sample is presented in Figure 2 and the related list of values is shown in Table 8. The table also provides information on the distribution of angler WTP for red snapper. CL assumed that the WTP for grouper, red snapper, dolphinfish, and king mackerel per angler per trip were randomly distributed and correlated according to a multivariate normal distribution. The incremental values reported for the "average" type angler in Table 8 were evaluated at the mean WTP whereas the "averse" and "avid" type anglers were evaluated at the 5th and 95th percentiles, respectively. Interestingly, there are some anglers (21%) who would have to be paid to keep any red snapper. At the extreme, these "averse" anglers would have to be paid nearly $83 to keep a second red snapper. This is still considerably less than the "avid" anglers at the other extreme would pay for the second red snapper. Keep in mind, however, that the CL sample consisted of anglers who were intercepted fishing in the Gulf of Mexico *and* the South Atlantic and who had targeted grouper, red snapper, dolphinfish, or king mackerel in the previous year. There is some discussion in CL comparing three other red snapper mean WTP estimates that appear in the literature ranging from $7 to $108 per fish (in 2003 dollars). They suggest that the variation in the estimates in the literature could be due to the differing number of substitute species modeled and the type of analysis (revealed vs. stated preference) performed in these studies. With regard to the latter difference, research has shown that the value of a recreationally caught fish estimated using stated preferences, as done in CL, can be systematically higher than the value of fish estimated using revealed preferences (Johnston et al. 2006).

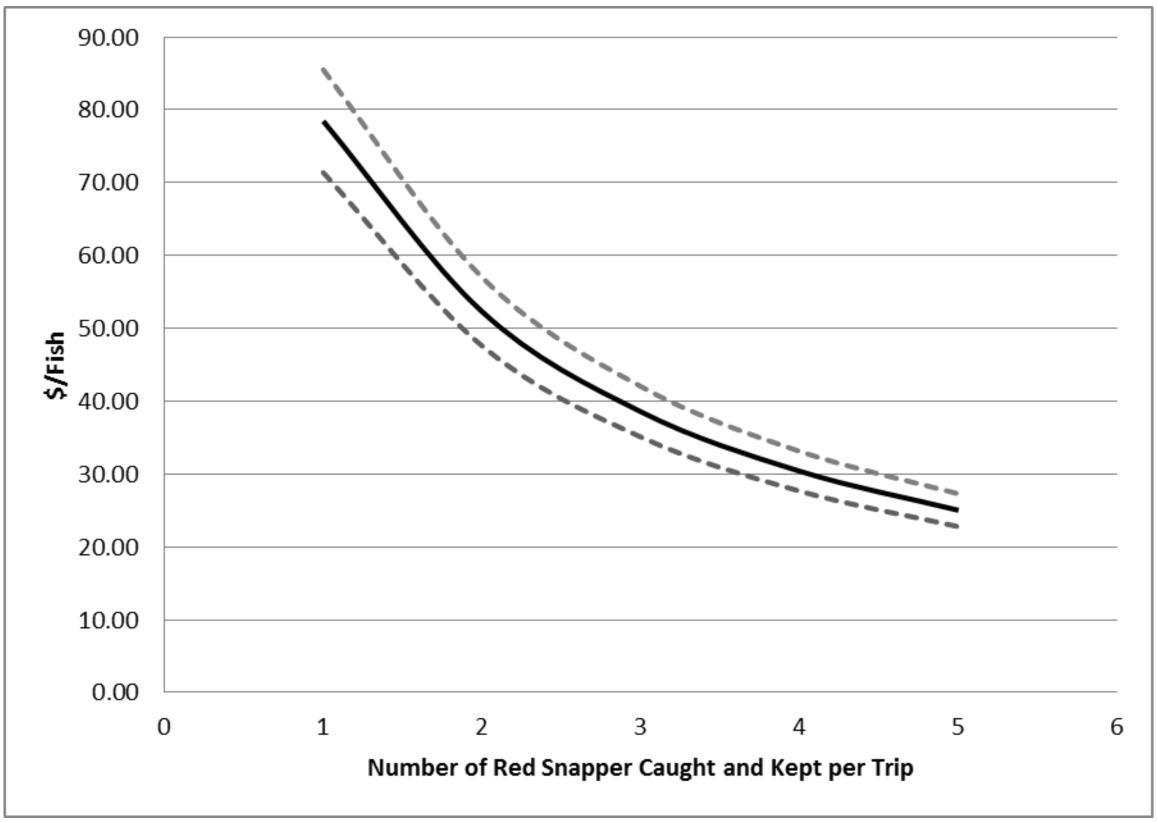

Figure 2. Average Incremental Value of Red Snapper Caught and Kept per Trip (2012 dollars)
Source: Carter and Liese (2012)

Table 7. Calculation of the Number of Anglers in the Gulf of Mexico Red Snapper "Market" for Recreational Fishing

				Target or Harvest Trips				Target or Harvest Anglers		
Year	All Trips	All Participants	Trips per Participant	Mean	95LB	95UB	Harvest % from MRFSS	Mean	95LB	95UB
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2004	26,429,207	3,502,875	7.55	480,524	352,518	608,530	83%	76,316	55,986	96,646
2005	23,289,807	3,323,263	7.01	302,721	228,617	376,825	82%	52,577	39,707	65,448
2006	23,292,921	3,643,179	6.39	360,439	288,900	431,978	80%	70,065	56,159	83,971
2007	24,289,264	3,561,577	6.82	462,667	363,206	562,129	85%	79,615	62,500	96,730
2008	24,789,852	3,188,477	7.77	273,283	207,049	339,518	84%	41,698	31,592	51,804
2009	22,597,249	2,846,427	7.94	368,665	254,690	482,641	78%	59,309	40,973	77,645
2010	21,047,433	2,714,931	7.75	186,771	114,027	259,515	73%	33,048	20,176	45,920
2011	22,575,779	3,048,472	7.41	320,355	229,838	410,873	82%	52,715	37,821	67,610

Table 8. Average Incremental Value of Red Snapper Caught and Kept per Angler per Trip by Anger Type (2012 dollars)

Starting #	WTP for next fish			WTP for next fish/pound (GW)		
of fish	Averse	Average	Avid	Averse	Average	Avid
1	-$83.35	$77.80	$238.08	-$14.59	$13.62	$41.68
2	-$55.56	$51.86	$158.71	-$9.73	$9.08	$27.79
3	-$40.95	$38.23	$116.98	-$7.17	$6.69	$20.48
4	-$32.28	$30.13	$92.19	-$5.65	$5.27	$16.14
5	-$26.59	$24.82	$75.94	-$4.65	$4.34	$13.30

Source: Carter and Liese (2012, Table 4) adjusted from 2003 to 2012 dollars using the January CPI from series CUSR0000SA0. The three types of anglers are defined according the estimated distribution of WTP for red snapper. "Average" anglers are defined at the mean WTP, "averse" anglers are defined at the 5th percentile, and "Avid" anglers are defined 95th percentile. The WTP for next fish per pound is based the 2012 projected weight of 6.34 lbs/fish WW converted to 5.71 GW using the 1.11 conversion factor. The confidence interval for all of the WTP estimates in the table is +/- 9%.

B. Marginal Value for Red Snapper based on the Bag Limit[4]

When the number of anglers and trips is fixed, the only way to increase aggregate harvest is by increasing harvest per trip. In this case a one fish increment in aggregate harvest occurs when one angler harvests one extra fish on one trip. Assuming that anglers are harvesting the number of fish they prefer from the number that they are able to catch, the primary constraint on harvest per trip is the daily bag limit.[5] In this case the only anglers able to increase their harvest with a bag limit increase are those who currently harvest the bag limit. A one fish increment in aggregate harvest is tantamount to allowing one of these constrained anglers to keep one extra fish on one trip. More precisely, the angler getting the extra fish would be the one with the highest WTP for it out of all of the constrained anglers. The marginal WTP in this instance is that angler’s WTP for

[4] The first two paragraphs are repeated from Agar and Carter (2012).
[5] The ability to catch and, therefore, harvest fish will also depend on stock effects (Anderson 1983). However, if the number of anglers and trips are fixed, then the change in stock effects should be negligible.

the next fish after the bag limit. Presumably, this WTP would be closer to the estimate shown for the "avid" angler shown in Table 8. As more fish are available via further increases in the recreational harvest allocation, the applicable marginal WTP would depend on how the fish (bag limit increases) are rationed among anglers and trips. However, currently no policy mechanism exists to ration recreational bag limit increases according to WTP.

In reality, the Council cannot change the bag limit for a subset of anglers or trips. Rather, the bag limit would have to be increased for all anglers on trips during the open season.[6] The bag limit approach approximates the marginal WTP for the next fish harvested per trip with the *average* WTP for the next fish harvested per trip following a bag limit increase.

Table 9 shows the distribution of recreational fishing trips in the Gulf of Mexico from 2004 to 2011 by the number of red snapper harvested per trip. Red snapper was harvested on less than 1% of all trips during each of these years with slightly more trips harvesting red snapper prior to 2007, possibly owing to the higher bag limit and longer seasons. The lower bag limit after 2006 also appears to shift the margin from four to two fish harvested per trip. Note that the margin in 2007 is not precise because the bag limit was changed in the middle of the year and it may take time for anglers to adjust. Assuming that the current distribution of trips is similar to 2008 through 2011, the effective marginal harvest is given by the current bag limit: two red snapper per trip. As a further check we can calculate the average harvest rate, or harvest per angler trip, at the 2012 allocation by dividing the harvest allocation by the relevant effort. The recreational allocation of red snapper is 3.959 million pounds whole weight (WW) in 2012 which is equivalent to 624,448 fish assuming 6.34 pounds per fish. Dividing the allocation in number of fish by the 390,618

[6] The Council could adjust the aggregate harvest more precisely by changing the season length, effectively changing the number of trips where the higher bag limit is available.

(7.41*52,715) trips targeting or harvesting red snapper in 2011 from Table 7 gives 1.60 fish per angler per trip which is close to the bag limit.

Assuming the two fish bag limit represents the margin, we can say that the *average* WTP for the third red snapper harvested per trip is $51.86 (+/- $4.67) or is $9.08 (+/- $0.82) per pound (GW) based on the results in Table 8. We use the lower bound, mean, and upper bound estimates as our low, medium, and high estimates, respectively, from this approach.

C. Marginal Value for Red Snapper using the Aggregate Demand for Red Snapper Harvest

In this section we present the measure of the recreational marginal WTP for red snapper at different harvest allocations using the aggregate demand curve for red snapper harvest. The aggregate demand curve for red snapper is constructed as the sum of the individual angler demands for red snapper harvest per trip at each cost per fish as shown in equation (6). We draw N parameters from the distribution of b, each corresponding to the preferences of one angler. The N parameters are used to create trip harvest demand equations for each angler which can then be summed at each trip cost, p, to create the aggregate demand for red snapper harvest as shown in equation (6). We use the number of anglers corresponding to the trips that targeted or harvested red snapper in 2004 as shown in Table 7 as N for our parameter draws in the construction of the aggregate demand for red snapper harvest. Fishing for red snapper during 2004 was the least regulated in recent history and should, all else equal, provide the most reasonable representation of unfettered fishing behavior. According to column nine of Table 7, there were $N = 76{,}316$ anglers in the "market" for red snapper in 2004 who took an average of $\bar{t} = 7.55$ trips. We also consider the lower and upper bound estimates of the number of anglers in the last two columns to calculate, respectively, “low” and “high” estimates of the marginal WTP using the aggregate harvest demand approach.

The aggregate demand curve for red snapper is shown in Figure 3 over the range of \$20 to \$150 per fish (originally in 2003 dollars) using our “medium” estimates of numbers of anglers (N = 76,316) and trips per angler ($\bar{t}$ = 7.55).[7] The recreational allocation of red snapper is 3.959 million pounds WW in 2012 which is equivalent to 624,448 fish assuming 6.34 pounds per fish. According to the curve in Figure 3, the marginal value of the next red snapper is \$123 per fish starting from 624,448 fish. This works out to our “medium” marginal WTP estimate \$22 per pound gutted weight (GW) using the assumed weight of 5.71 (6.34/1.11) pounds per red snapper. It is very important to note, however, that this result is sensitive to the number of anglers (N) assumed in the construction of the aggregate harvest demand curve. In fact, the resulting marginal value is almost proportional to the number of anglers. Using the lower bound number of red snapper anglers from Table 7 gives our “low” marginal WTP estimate of \$17 per pound while using upper bound the number of anglers yields our “high” marginal WTP estimate of \$25 per pound.

As an extreme consider the construction of the aggregate demand curve using the lowest estimated number of participants shown in Table 7. Besides 2010 when the fishery was closed due to the DWH event, the lowest number of anglers listed is the lower bound of the estimated number of anglers in 2008 of 31,592. Using an aggregate harvest demand curve calculated with 31,592 anglers, the estimated marginal value per pound at the 2012 allocation is \$11.05.

[7] We evaluated the expression for aggregate harvest demand from p equals \$20 to \$150. The price (vertical) axis was then scaled from 2003 to 2012 dollars using the January CPI from series CUSR0000SA0. There are more details regarding the derivation of the aggregate demand curve in Appendix A.

Table 9. Distribution of Recreational Fishing Trips in the Gulf of Mexico by Number of Red Snapper Harvested per Angler per Trip

Fish/ Angler/Trip	2004	2005	2006	2007	2008	2009	2010	2011
0	26,227,157	23,166,848	23,138,422	24,133,792	24,665,820	22,464,501	20,973,501	22,472,429
1	115,446	75,148	94,550	76,734	66,963	65,033	26,350	59,267
2	36,441	20,320	23,460	48,091	54,054	61,586	46,015	42,436
3	16,660	10,739	13,358	12,569	2,275	3,280	1,280	1,646
4	26,653	13,484	18,838	14,119	594	1,068	144	-
>4	6,850	3,268	4,292	3,959	146	1,781	143	-
Total	26,429,207	23,289,807	23,292,921	24,289,264	24,789,852	22,597,249	21,047,433	22,575,779
>0	202,050	122,959	154,498	155,473	124,033	132,748	73,932	103,350
>0 (%)	0.76%	0.53%	0.66%	0.64%	0.50%	0.59%	0.35%	0.46%

Source: MRFSS, based on fish kept (A). The bag limit for red snapper was 4 fish from 2004 and was decreased to 2 fish starting May 2nd 2007.

We can also use the aggregate harvest demand curve to measure the economic benefits of an increase in the allocation to the recreational sector by integrating under the curve between two allocation levels. For example, starting from the 2012 allocation and using the medium estimate (76,316 anglers), the economic benefits of a 1% increase is $767,000. This result is also sensitive, though not strictly proportional, to the number of anglers assumed in the aggregation.

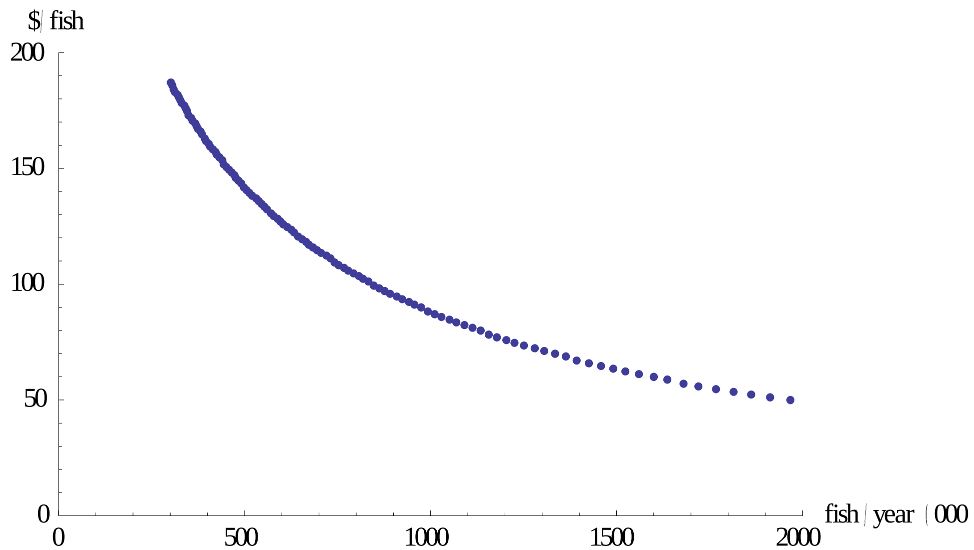

Figure 3. Aggregate Demand for Red Snapper Caught and Kept, Medium Estimate (2012 dollars)

D. Concluding comments on recreational analysis

We presented two approaches that translate changes in allocations into changes in the WTP for recreationally harvested red snapper at the margin. The approaches take the number of anglers and the number of trips per angler as fixed. The first assumes that the changes in allowable harvest for the recreational sector come about via changes in the bag limit and measures marginal WTP at the current bag limit. This approach is relatively simple to implement, but does not account for the sorting of anglers according to the highest WTP for the next fish. Of course, as we noted earlier, there currently is no policy mechanism in place to ration bag limits according to the WTP for red snapper.

The second way we suggested to measure the marginal WTP of recreationally harvested fish at the current allocation is based on the aggregate demand curve for red snapper harvest. We estimated this demand curve and then found the marginal WTP at the current allocation. This approach sorts anglers according to their WTP for red snapper harvest per trip.

The estimates from the two approaches are summarized in Table 10. The second method estimate is relatively higher than the first because this approach accounts for the sorting of anglers according to WTP for red snapper harvest per trip.

There is a more fundamental difficulty related to the assessment of the marginal WTP for recreational harvest for use in fishery allocations.[8] Unlike commercial fishing there is no market price for recreationally harvested fish. Furthermore, most recreational fishing trips are not purchased in the market. This is important because in the recreational context there is no market price that can be used to place an upper or lower bound on the marginal WTP for harvest. Randall (1994) made this observation for the travel cost approach to non-market valuation, but the problem is more general. As noted by Easley et al. (1989 p. 47), "it seems reasonable that the values for improvement measured per trip to a given recreation site cannot exceed the value of a typical trip to that site." This upper bound is not very useful in decisions about fishery allocations. Carter et al. (2008) attempted to overcome this issue by using the market prices of charter trips to derive the relevant marginal values. However, their approach is of limited use in the absence of good data on the market prices of for-hire services.

[8] The remainder of this section is repeated from Agar and Carter (2012) because we feel it is important to emphasize these issues.

Even if we had accurate, cardinal measures of the marginal value of recreationally harvested fish there is still much work to be done before we can calculate and predict the economic effects of fishery allocation decisions on the recreational sector. The most recent review of recreational economic data at NMFS (McConnell, 2006 p. 10) concluded that "allocation decisions will have to answer the conceptual issues of how regulations affect catch, effort and economic value and how changes in fish stocks influence recreational behavior and value." NMFS continues to work on answers to address these important issues.

Table 10. Summary of Marginal WTP Estimates for the Recreational Harvest of Red Snapper in the Gulf of Mexico at the 2012 Allocation

Method	low	medium	high
Bag Limit	$8.26	$9.08	$9.90
Aggregate Harvest Demand	$17.41	$21.53	$25.04

4. Study Results and Conclusions

This study finds that the 2012 Gulf of Mexico red snapper allocation for the commercial and recreational sectors is not economically efficient because the net benefit of the last unit of quota differs between the two sectors. Table 11 shows that the magnitude of the red snapper estimates are higher for the recreational sector relative to the commercial sector. The highest estimate for commercial sector is still lower than the lowest estimate for the recreational sector. This suggests that the economic efficiency of red snapper use in the Gulf of Mexico and the economic benefits to the nation could be increased by modifying the current allocation. However, we cannot confidently determine the economically efficient allocation level with existing methods and data.

On the commercial side, improving the quality of allocation and share prices is critical since these quantities provide valuable information on the net benefit of additional units of quota. The majority of the allocation and share prices encountered in the analysis were very low (i.e., less or equal to one penny).[9] While there may be reasons for some of these low transaction prices (e.g., bartering, in kind services, transferring allocation between own accounts), it is vital to ensure that the correct transactions prices are reported, if these data are to be used in economic analyses.

A second consideration on the commercial analysis is the recognition this sector may have not fully adjusted to the new IFQ program and to the significant changes in ACLs. Average quota levels during the first 5 years of the IFQ program were about 2/3 of those average levels observed during the preceding five years of the program.

A third concern with the commercial analysis is that changes in net benefits to the consumers of red snapper are not accounted for due to the lack of retail data. However, it is likely that these

[9] As noted earlier, these low value figures were not used in the analysis; however, potentially valuable information is lost when transaction prices are not accurately reported.

changes would be relatively low for small allocation changes because of the wide availability of domestic and imported substitutes for red snapper, such as other snapper species and grouper.

The recreational analysis assumed that the number of anglers and the number of trips across time and space would not change as the allocation to the recreational sector changed. This assumption was used in our previous analyses of grouper allocations in the Gulf of Mexico (Agar and Carter; Carter et al. 2008) and is acceptable for measuring changes in recreational net benefits for relatively small allocation changes.

Two alternative approaches were used to measure the net benefit of the next pound of fish at 2012 allocation of harvest to the recreational sector. The first approach is based on the relevant bag limit and measures the *average* incremental willingness-to-pay for red snapper harvested per angler per trip. This approach does not explicitly address the sorting of anglers along the aggregate harvest demand schedule for the recreational sector. The outcome of this sorting will ultimately determine the incremental net benefit relevant for changes in aggregate harvest. The second approach attempts to incorporate this sorting by using an estimate of the aggregate recreational harvest demand curve.

We also have general concerns regarding the usefulness of existing recreational valuation techniques for measuring the net benefit of changes in harvest in the recreational sector. Such approaches are useful for measuring changes in net benefits within the sector. However, these methods should be used with caution when comparing net benefits with the commercial sector due to the lack of a relevant market price to bound the estimates in the recreational sector. Our previous work attempted to use charter trip prices to address this concern, but no current data on charter prices exist with which to update this analysis.

Lastly, we note the fundamental difference in the scale of allocation changes that are feasible in the commercial and recreational sectors under the current management structure. The Council can "fine-tune" the allowable commercial harvest down to the last pound of fish by changing the ACL, thus allowing the IFQ system to allocate the harvest. In the recreational sector, however, the Council currently can only allocate harvest in "chunks" based on the bag limit and season length. As discussed above, no policy mechanism exists for the Council to allocate one pound of fish to the recreational sector. Therefore, unless alternative policy mechanisms are considered that enable allocating harvest to the recreational sector on a finer scale, efficiency analysis such as the one presented in this report, need to be reevaluated not at the "margin" (i.e., one pound of fish), but at feasible chunks based on the available harvest controls. In this case the harvest chunks and the corresponding "marginal" values will depend critically—much more so than in the commercial sector—on *how* the additional quota is implemented in the recreational sector. One potential way to manage recreational harvest on a finer scale would be to encourage trade of allocation between the commercial and recreational sectors. Inter-sector trading would allow the market to provide valuable price signals to help ensure that the red snapper quota is allocated efficiently and in a way that provides the greatest economic benefits to the nation. However, more research on market-based solutions to inter-sector allocation is needed to determine the benefits and costs of implementation.

Table 11. Summary of study findings

		Commercial	Recreational
2012 Allocation (%)		51%	49%
2012 Allocation (MP, GW)		3.71	3.57
	Lowest	$2.65	$8.26
MWTP/lb.	Medium	$2.94	$9.08 or $21.53
	Highest	$3.23	$25.04
Is current allocation economically efficient?		No	No

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6. Appendix A: Mathematica Notebook for the Derivation of Aggregate Red Snapper Demand

<<DOUBLE-CLICK THE IMAGE BELOW TO OPEN THE PDF FILE>>

Aggregate Demand for Sportfishing Harvest of Red Snapper in the Gulf of Mexico based on the 2003 Sportfishing Stated Preference Choice Experiment

David W. Carter

NOAA SEFSC

10/09/2012

Individual angler

- **Behavioral equations**

Total willingness-to-pay (WTP) function

In[1]:=
```
twtp = b ArcSinh[h];
```

Marginal WTP function. Note that the b parameter is the marginal WTP for an infinitesimal change starting from zero fish.

In[2]:=
```
mwtp = D[twtp, h]
```

Out[2]=

$$\frac{b}{\sqrt{1+h^2}}$$

WTP function for a discrete change from h0 to h1

In[3]:=
```
dwtp = Integrate[mwtp, {h, h0, h1}, Assumptions → {h ≥ 0, h0 ≥ 0, h1 ≥ 0, h1 ≥ h0}]
```

Out[3]=
```
b (-ArcSinh[h0] + ArcSinh[h1])
```

Demand (Inverse WTP) function and choke price. Note that the choke price is the b parameter and it can be negative (i.e., where you would have to pay the angler to keep the fish).

In[4]:=
```
hq = h /. FullSimplify[Solve[mwtp == p, h]][[2]]
Refine[Solve[hq == 0, p], p ≥ 0]
```

Out[4]=

$$\frac{\sqrt{(b-p)\ (b+p)}}{p}$$

Out[5]=
```
{{p → -b}, {p → b}}
```