NOAA Technical Memorandum NMFS-SEFSC-576

ECONOMIC FRAMEWORK FOR FISHERY ALLOCATION DECISIONS WITH AN APPLICATION TO GULF OF MEXICO RED GROUPER

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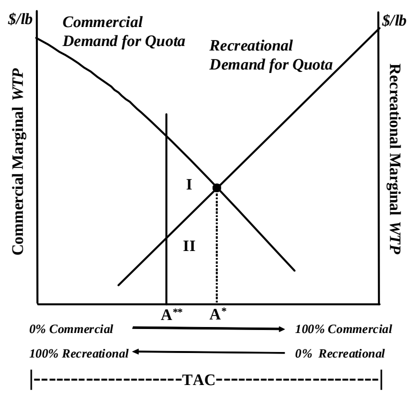

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Contents

Figures

1. Introduction

The Gulf of Mexico Fishery Management Council is considering policies that would change the allocation of fishery harvest between the commercial and recreational sectors. This report introduces a framework to evaluate the economic consequences of these allocation policies.[1] Specifically, we show how, in principle, to judge the economic efficiency of fishery allocations and to measure the potential benefits and costs of allocation decisions. The economic framework is applied in a case study of red grouper harvest in the Gulf of Mexico. The case study illustrates the extent to which the available measurement methods and data can provide results useful for policy purposes. Specifically, the goals of the case study are: 1) to examine the efficiency of the existing red grouper TAC allocation 2) to offer preliminary estimates of the gains and losses for small redistribution of the red grouper TAC, and 3) to assess whether the available data are sufficient to conduct a theoretically rigorous economic analysis of allocation for other species in the Southeastern U.S.

The report is organized as follows. The next section introduces the key concepts of economic value in the context of fishery allocations. Section 3 shows how these concepts can be used to define the economically efficient allocation and measure the benefits and costs of reallocation. The potential pitfalls of using alternative metrics to make economic allocation decisions are described in Section 4. The fifth section summarizes the results of the red grouper case study and discusses the implications of the assumptions used in the analysis. More details about the technical aspects of the case study are presented in the Appendices.

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[1] Additional reviews of the economic principles relevant to fishery allocations can be found in Edwards (1990, 1991) and Green (1994).

2. The Economic Value of Fishery Quota

Economic value is shaped by tastes and preferences and, in general, we have a higher value or willing-to-pay (*WTP*) for those goods and services that provide greater satisfaction and benefit.[2] However, given limited amounts of time and money, we are unable to obtain all of the goods and services we value. Our *WTP* for a good or service in excess of the cost of purchasing it measures our net economic value or *consumer surplus*. A similar rationale applies to firms that are unable to supply all that they want at given price because time and production resources are scarce and costly. The difference between the market value of a good or service and its production cost is the net economic value or *producer surplus* to firms. The total net economic value of a good or service is the sum of consumer and producer surpluses it affords.

The consumer and producer surplus related to fishery quotas are measured with reference to activities in different fishing sectors. In the commercial sector, there is consumer surplus from the retail sale of fish and producer surplus from the harvesting, distribution, processing, and the sale of fish at the wholesale and retail levels. These consumer and producer surplus values can be measured at different levels of fishery quota with information about market transactions and the cost of harvesting.

In the recreational sector, fishery quota generates producer surplus for services provided by for-hire operations and consumer surplus for recreational anglers. The former can be measured with information about the fees and costs for charter and head boat trips with different harvest characteristics (e.g., catch, keep, size, species composition). The latter is measured by comparing anglers' *WTP* and cost for fishing trips with different harvest characteristics.

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[2] An accessible introduction to the concepts of economic value as applied to natural resources is available in Lipton et al. (1995).

Changes in fishery quota cause changes in the consumer and producer surplus that can be generated in the commercial and recreational sectors. The value of changes in these surpluses for very small changes in quota is measured in terms of the *demand* per pound of quota. This concept is illustrated in the top left panel of Figure 1 using the commercial sector's demand curve for different levels of quota from the total allowable catch (TAC). The demand curve traces the commercial sector's maximum *WTP* for each pound of quota, and is downward sloping because each extra or *marginal* pound adds successively smaller amounts to consumer and producer surplus. Therefore, the commercial sector is *WTP* more per pound for additional quota when the quota is small and is *WTP* less per pound when the quota is large and less restrictive.

The total value of fishery quota to a sector is measured by summing the total *WTP* for each successive pound of fish until the quota is exhausted. Geometrically, this total value is the area under the quota demand curve. Again, this concept is demonstrated for the commercial sector in the top left panel of Figure 1 where the total value of a quota at A* is shown as the shaded area under the quota demand curve. Any reduction in the quota due to reallocation, say from A* to A**, will result in a loss in consumer and producer surpluses equal to the total value associated with quota A* minus the total value associated with quota A**. This loss is depicted by the shaded area in the top right panel of Figure 1.

A curve corresponding to the recreational sector's downward-sloping demand for quota is shown in the bottom left panel of Figure 1. Note, however, that the recreational sector demand curve has been "flipped" relative to the commercial demand curve because the recreational *WTP* per pound of quota is measured using the vertical axis on the right. The total net benefits to the recreational sector for quota of A* is depicted by the shaded area shown in the bottom left panel of Figure 1.

Note that in an open-access fishery, there is no explicit price for an additional unit of quota. In a fishery with transferable harvesting privileges (e.g. ITQs), however, fishing sectors must pay market price to purchase additional units of quota. This price would be reflected in the graphs of Figure 1 as a horizontal line, and the net benefit or surplus to each sector of changes in quota would be measured by changes in the shaded areas above this line.

3. The Economic Allocation of Fishery Quota

The equimarginal principle specifies that the economic value of a fishery is maximized when the *WTP* per pound by one sector to increase its allocation matches the *WTP* per pound forgone by the other sector as its allocation is reduced. At this point, the economically efficient allocation is achieved because the highest economic value is obtained from the TAC at the least cost. In this way the consumer and producer surplus from the use of the TAC is maximized.

The bottom right panel of Figure 1 demonstrates the equimarginal principle with quota demand curves for the commercial and recreational sectors shown in the same graph. Note that the commercial sector's *WTP* per pound of quota decreases as the allocation to this sector increases from 0 percent to 100 percent, as shown from left to right along the horizontal axis. Correspondingly, the recreational sector's *WTP* per pound of quota decreases as more quota is assigned to this sector, as shown from right to left along the horizontal axis. The economically efficient allocation is given at A* where the quota demand curves from the two sectors intersect.

Consider a policy that allocates additional quota to the recreational sector, as shown in the lower right panel of Figure 1 by moving the current allocation from A^* to A^{**}. At this new allocation, the recreational sector obtains an increase in economic value given by the area (II) under its demand for quota curve between A^* and A^{**}. However, the cost in terms of forgone value to the commercial sector is given by the area (I + II) under its demand curve between these two points. In this case, the forgone benefits to the commercial sector exceed the additional gains to the recreational sector as measured by area I. A similar net loss of societal benefits would occur if the allocation to the commercial sector exceeded A*.

4. A Cautionary Note Regarding Alternative Economic Allocation Metrics

Stakeholders with vested interests in the outcomes of allocation decisions are often tempted to advance alternative economic arguments to secure a larger share of the resource.[3] For instance, commercial fishermen may discount the value of recreational fishing because it is primarily a leisure activity, while sportfishers like to point out that anglers' expenditures often exceed commercial dockside revenues. In the latter case, the recreational sector may argue that it should receive a larger share of the catch because it spends more than the commercial sector.

These commonly articulated arguments can lead to inefficient economic allocations because they confuse the meaning of economic value. Specifically, a characterization of recreational fishing as devoid of value incorrectly presumes that only markets bring about value, whereas a focus on angler expenditures and commercial revenues ignores the costs of fishing. Commercial revenues alone are not a measure of net economic benefits because they do not account for costs of production. As for spending in the recreational sector, expenditures are *costs* to sportfishers that detract from the total benefits received from the recreational fishing experience. Again, the *net* economic value or consumer surplus to anglers is the value remaining after deducting their costs of fishing. While it is true that angler expenditures represent gross

[3] Further discussion of the confusion surrounding economic value and allocation metrics can be found in Edwards (1990, 1991), Green (1994) and Kirkley et al (2000).

benefits or incomes to the sellers of recreational fishing supplies and services, the *net* benefit or producer surplus to the sellers is the income remaining after deducting their costs of production. Therefore, without further analysis of the costs of fishing and the supply of fishing related services, we do not know if the recreational net economic value associated with expenditures are greater or less than the net economic value generated by commercial production. This caution also applies to the secondary effects or so-called *economic impacts* of commercial and recreational fishing activities on spending, income and employment in the local and regional economy.

As presented in Section 2, economic value or benefits *net* of the resource costs is the correct measure to use if we are interested in the efficiency of fishery allocation. Alternative allocation metrics, such as expenditures, revenues or economic impacts, will suggest different allocations that may advance other objectives, but have little to do with economic efficiency.

5. Economic Allocation of Red Grouper Quota

5.1. Introduction

According to the equimarginal principle, the total economic value of the red grouper TAC is maximized when the marginal value gained by a sector receiving a larger allocation is just equal to the marginal value lost in another sector due to a corresponding smaller allocation. Finding this economically optimal allocation between commercial and recreational sectors requires information about how the allocated harvest generates value in these components of the fishery. In this section we use the models described in Appendices 1, 2, and 3 to evaluate the effects of red grouper allocation policies on the commercial and recreational sectors in the Gulf of Mexico. After an overview of the methods documented in the Appendices, we consider the efficiency of the current allocation and then determine what can be said regarding the optimal allocation and the economic effects of changes in allocation. We use 2003 as the base year to represent the 'current' allocation because it was a year encompassed by both the recreational and commercial data used in the analysis. Also, after 2003, there were significant changes in the commercial and sportfishing regulations for red grouper that could complicate the measurement of the efficient allocation and the effects of reallocation.

5.2. Overview of Methods

Studies were conducted to evaluate the economic value of red grouper harvested in the commercial and recreational fisheries of the Gulf of Mexico. The goal of this research was to estimate the quota demand schedules for each sector as shown in Figure 1. This section presents an overview of the methods and data used in these analyses. The complete documentation appears in the Appendices.

The analysis of the demand for quota by the commercial sector focused on vessels with vertical lines and long lines. Data about landings and fishing effort by commercial vessels that landed red grouper along the west coast of Florida were obtained from Florida's Marine Fisheries Trip Ticket database. Trip-level information was extracted about landings and dockside prices by species, area fished, county of landing, and gear-specific fishing effort. Data about harvesting costs are not available in the Trip Ticket database and attempts to link other relevant datasets were unsuccessful. Consequently, our model of commercial fishing assumes that fishermen cannot readily change input levels to adjust costs during a fishing trip. In other words, we assume that fisherman take costs as fixed during the trip and select the harvest mix that maximizes trip revenue.

The revenue on each trip from the Trip Ticket data was modeled separately for vertical lines and long lines as a function of fish prices, the location of the fishing ground, county of landing, season, presence of seasonal closures, and storm activity. The parameters of this function were used to derive the *WTP* for each pound of red grouper harvested on each trip. The aggregate demand for quota was calculated by summing the demands over all trips and both gear types. Note that the aggregate demand for quota represents an empirical version of the commercial demand for quota presented in Figure 1.[4]

The analysis of the demand for quota by the recreational sector focused on the charter boat fleet in the Gulf of Mexico, primarily because of data limitations. However, historical data suggests that the charter fleet accounts for the majority of target and catch effort for red grouper.[5]

There was not enough information to trace out the full demand schedule for quota in the recreational sector using the charter fleet data. Therefore, we sought to identify at least one point on this schedule of value. Our approach can be summarized as follows. Prices for charter trips vary according to the services offered by each operator and the relative demand by anglers for these services. Key services in this mix include the expected number and size of fish harvested. We hypothesize that these expected harvest characteristics vary by county and are manifest in varying charter prices. For example, all else equal, a charter boat operating in a county where the number and/or weight of fish is higher than average will be able to charge relatively more for a trip. The goal of the research on the charter sector presented in Appendix 2 is to figure out how much more. In general, the extra charter price paid on average for another pound of fish represents one point on the recreational demand for quota.

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[4] We also attempted to estimate the demand for red grouper quota by consumers at the retail level. Consumer demand was estimated as a function of disposable income, Gulf of Mexico landings and fresh grouper imports. However, due to the poor fit of the equation, we excluded consumer demand from the model. This exclusion is acceptable to the extent that consumers can substitute other fish species or types of foods for red grouper when the price and/or availability of red grouper changes.

[5] See the description of the recreational fishery in the Draft Reef Fish Amendment 30B.

The expected harvest characteristics were measured for each county with the average number of fish kept and average weight per fish reported in the MRFSS from 1992-2001. Information about charter prices and basic trip characteristics were obtained in a 2002-03 telephone survey of charter operators. Note that the methods described in Appendix 2 produce one point on the recreational demand schedule for quota of any species. Appendix 3 shows how this value is converted into a point on the sportfishing demand for red grouper quota.

5.3. Efficiency of the Current (2003) Allocation

As described in the previous section, Appendix 1 reports on the estimation of an aggregate commercial demand curve for red grouper quota in the Gulf of Mexico. The curve suggests that the marginal *WTP* is approximately \$1.14/lb for the commercial sector at its 2003 harvest of 4.94 million pounds (MP) of gutted weight.[6] Interestingly, this is very close to the estimated mean marginal *WTP* of \$1.21/lb for the recreational sector as reported in Appendices 2 and 3, suggesting that the current (2003) allocation may be efficient or, at least, not too far off. Note, however, that the 95 percent confidence interval for the recreational marginal *WTP* per pound of red grouper ranges from \$0.30 to \$2.12. Similar confidence intervals could not be calculated for the estimates of marginal *WTP* in the commercial sector.

Figure 2 illustrates what we can learn about the efficiency of the existing allocation with information about the commercial demand curve for quota and a point estimate from the recreational demand for quota. Figure 2 is a modified version of the bottom right panel of Figure 1, and depicts a downward-sloping commercial demand for quota and the commercial harvest of red grouper in 2003. Figure 2 also tracks the marginal value of quota to the recreational sector

[6] All dollar values are denominated in 2003 dollars unless indicated otherwise.

on the right vertical axis, and shows one point *E* on the recreational demand for quota. Using 2003 as the base year, the overall harvest of 6.21 MP pounds landed is approximately 79.5 percent (4.94 MP) commercial and 20.5 percent (1.28 MP) recreational.[7] For the sake of discussion, assume that the recreational mean marginal *WTP* and the commercial marginal *WTP* are at the estimates reported above. As shown on Figure 2 the marginal *WTP* per pound is higher for recreational fishing ($1.21) than for commercial fishing ($1.14). This suggests that the extra benefits of a larger allocation to the recreational sector would be greater than the reduction in benefits to the commercial sector due to a corresponding smaller allocation. However, without the complete quota demand curve for the recreational sector we do not know how much to reallocate to achieve the efficient allocation.

The location of the efficient allocation depends on the shape and the slope of the demand for quota in the recreational sector. A number of linear possibilities are shown in light shading around point E. The maximum reallocation would correspond to the case of a flat demand curve for recreational quota.[8] Based on the commercial demand for quota calculated in Appendix 1, the commercial harvest demanded when the cost is $1.21/lb is about 4.77 MP. This suggests that the most that would be economically reallocated from the commercial to the recreational sector would be about 0.168 MP, given the conditions that existed in 2003. Caution should be used, however, in interpreting this example because the 95 percent confidence interval around the recreational mean marginal *WTP* per pound of red grouper contains the commercial estimate of marginal *WTP* at the current (2003) allocation.

[7] There was no separate quota management for the red grouper fishery in 2003. Red grouper were considered part of the shallow water grouper quota.

[8] A flat recreational quota demand curve implies that the demand for quota is perfectly elastic so that recreational effort does not change in response to quota changes. This is an unlikely assumption over the entire range of quota demand. However, it may be reasonable for small allocation changes in the immediate area around the point estimate, E.

5.4. Effects of Allocation Changes

The Gulf of Mexico Fishery Management Council proposed a one percent change in the allocation of the red grouper TAC between the commercial and recreational sectors.[9] Various levels for the TAC are considered for the fishery. However, for illustration purposes, we will assume that the base TAC and allocation are given by the harvest levels observed in 2003. In this case, the hypothetical TAC would be 6.21 MP allocated 20.5 percent recreational (1.28 MP) and 79.5 percent commercial (4.94 MP).[10] The following discussion examines the potential cost to the commercial sector and benefits to the recreational sector of a one percent change in this allocation in favor of the recreational sector.

The methods for calculating the welfare effects of discrete changes in the commercial quota for red grouper are described in Appendix 1. Essentially, the approach calculates the area under the commercial demand for quota between the base and proposed allocation levels as shown in the top right panel of Figure 1. Calculated in this manner, the one percent reallocation reduces commercial landings from 4.94 MP to 4.88 MP and costs the commercial sector $71,628. This calculation is shown as area B plus area C in Figure 3, where the rounded amount of $72k is marked with a bracket.

The one percent reallocation to the recreational sector would increase landings from 1.28 MP to 1.34 MP of gutted weight. Measuring the welfare effect of this .06 MP increase is difficult because, as noted above, the valuation model described in Appendix 2 only generated an

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[9] Draft Reef Fish Amendment 30B: Gag – End Overfishing and Set Management Thresholds and Targets, Red Grouper – Set Optimum Yield TAC and Management Measures, and Marine Reserves October 2007.

[10] For reference, the "no action" proposal by the Gulf of Mexico Fishery Management Council in Reef Fish Amendment 30B allocates 6.56 MP of gutted red grouper as 23 percent recreational and 77 percent commercial.

estimate of one point along the quota demand curve for the recreational sector. If we assume, however, that the quota demand curve for this sector is relatively flat[11] in the area of a one percent change, then the value of this additional harvest to the recreational sector is simply the estimated mean marginal *WTP* times the change in harvest, or $75,187(±$56,546).[12] This calculation is shown as the sum of areas A, B, and C in Figure 3 where the rounded amount of $75k is marked with a bracket. Note that the assumption of a flat recreational demand for quota curve may not be appropriate for larger allocation changes. This assumption is discussed further in the next section.

The benefits and costs of the one percent reallocation of the (2003) red grouper harvest are summarized in Figure 3. The figure illustrates the comparison of the costs in terms of foregone landings value in the commercial sector with the benefit in terms of the value of additional landings in recreational sector. This comparison reveals that the benefits of the reallocation to the recreational sector**,** $75,187 (areas A, B, and C), are greater than the loss of benefits to the commercial sector, $71,628 (areas B and C). In this case, the one percent reallocation may improve the efficiency of the red grouper harvest by increasing the net value of the fishery by approximately three thousand dollars.

5.5. Considerations and Issues

As stated in the Introduction of this report, the red grouper case study had three primary goals. The first two, related to the efficiency of the "current" allocation and the economic effects of small reallocations, were addressed in the previous two sections. Here we address the final task of assessing the sufficiency of available data to conduct a theoretically rigorous economic

[11] See footnote 8 for the implications of a flat recreational demand for quota.

[12] Using the exact (unrounded) change in recreational harvest of 62,138 pounds this calculation is given by 62,138*$1.21(±$0.91).

analysis of reallocation for other species in the Southeastern U.S. This assessment is considered in terms of the acceptability of the assumptions and methods required to examine the economic allocation of red grouper and other species with existing data. Specifically, we consider the potential limitations inherent in the key assumptions of the analyses conducted for the commercial and recreational sectors in the red grouper case study. The goal of the discussion is to enable readers to determine whether the assumptions are reasonable enough to use the results for policy making. Where possible, we also indicate the primary reason for the key simplifying assumptions and what additional data would be necessary to relax these assumptions in future work about the economics of allocation.

The analyses of the commercial and recreational sectors are based on 'current' conditions. We used 2003 to represent the base case, current conditions. For the commercial sector analysis this means that the fleet configurations, amount of fishing effort for each species, and resource conditions pertain to the levels observed in 2003. The model of the commercial sector then measures economic effects in terms of changes in red grouper target effort. For example, trips that are less efficient at harvesting red grouper would stop harvesting this species with a reduction in commercial allocation, while the resource conditions and the fleet configuration are assumed to remain fixed at 2003 conditions. The potential shifting of fishing effort across fisheries and seasons, or the potential entry and exit of vessels to and from the industry is not modeled. In addition, this type of analysis is static in that the effect of changes in commercial effort on resource biomass and vice versa is not modeled. A bioeconomic model could be constructed to address these types of feedback and measure the effects of reallocation over time. However, we currently do not have the data to accurately parameterize such a dynamic model. At a minimum, we would need information about the population dynamics of key species, and harvesters' decisions about whether to participate in a fishery and how many trips to take. Also, it would be useful to have information about the effects of environmental factors on the fishery system and spatial characterizations of effort and stock conditions. Note, however, that a bioeconomic model is not necessary if we are interested in measuring the annual effects of a small reallocation. In the near term, the alternative, static model used in the red grouper case study may be the only viable option given the considerable amount of information necessary to implement a dynamic bioeconomic model.

There are several limitations specific to the analysis of the commercial sector. First, the commercial sector analysis does not report measures of the uncertainty surrounding the results. The model predicts the most likely value for the commercial sector quota demand and value, but it would be useful to consider how much confidence we have in a range of other likely or expected values. New methods must be developed to numerically estimate statistical confidence intervals on our estimated values. Second, data limitations restricted the analysis of the commercial sector to measuring benefits from the harvesting sector. The potential net value to consumers and fish retailers is omitted, as is the potential net value derived from the distribution, processing, and wholesale markets. To measure the effects in these higher level markets we would need information about the consumer demand for fish as a function of domestic and international production and the product flows and markups as the harvest moves from the dockside to retail markets. Third, although separate state and Federal databases collect trip-level information about commercial fishing activities, none of them collect all desired data elements. This study used the Florida Trip Ticket database because the commercial fishery for red grouper occurs almost exclusively in the state of Florida. Florida Trip Tickets include two critical elements, landings and dockside prices by species, but do not include trip costs. The Federal logbook program includes landings, trip costs and crew size, but does not include dockside prices. It is not known at this time if suitable proxies for dockside prices could be merged with the Federal logbook data to estimate a commercial sector demand for quota for species that are harvested throughout the Gulf of Mexico.

A static, annual effects model was used for the recreational sector due to the lack of sufficient data about angler trip-taking behavior and participation. However, the assumptions underlying the calculation of changes in the value of recreational fishing associated with reallocation are more subtle. With existing data, we could only estimate a point on the recreational demand for quota and had to make an assumption about the shape of the rest of the curve. We assumed that the recreational demand for quota is flat, suggesting that the average value per pound is constant for the recreational sector. One advantage of this assumption is that the results will always be an upper bound on the potential benefits or losses to anglers from a change in allocation to the recreational sector. This is true regardless of the size of the reallocation, but the overestimation will be greater the larger the change in allocation.

In general, the flat recreational demand curve for quota suggests that the change in value when quota changes occurs because of changes in the number of anglers, the average number of trips per angler, and/or the average red grouper harvest per trip. Unfortunately, we were unable to determine which of these changes occurred with the existing data and methods. For small reallocations, however, it is likely that the effort levels would remain relatively constant and that the harvest changes would occur due to changes in the average harvest per trip. This is especially likely if reallocations are implemented via policies, such as bag and size limits, that directly affect harvest per trip.

Larger reallocations could cause a significant change in the number of anglers or trips, and our estimates of the economic effects on the recreational sector will be missing a key component of recreational value. Clearly, trips could change with a larger allocation of the TAC, for example, if anglers take more trips because there is more available harvest. In such cases there will be additional economic effects because for-hire operators will experience changes in producer surplus as the number of trips and/or participants change. Again, it is important to emphasize that this not an oversight in the analysis. Rather the inability to model how recreational trips might change in an economically meaningful way with TAC reallocations is due to the lack of data. We are working on models to predict how effort would change as allowable harvests change. However, these models are data intensive, requiring observations for recreational effort, harvest, and regulations over time, along with key factors to control for changes in economic, resource and environmental conditions. One such model was used to forecast changes in headboat effort for the economic analysis of red snapper alternatives in the Reef Fish Amendment 27/Shrimp Amendment 14 (GMFMC 2007).

There are other important assumptions inherent in the analysis of the recreational sector. Most notably, the estimated value per pound of fish was not species-specific and is based on data from the charter sub-sector. Due to data limitations, the measure of pounds per trip used in the model included all species harvested by offshore charter trips. Appendix 3 adjusted the overall value per pound of fish for use in the analysis of red grouper. However, more research is necessary to determine how anglers actually value species differently beyond general characteristics such as weight and the expected harvest per trip. Also, we need to determine if the values estimated in the red grouper case study from the charter market are applicable to anglers fishing from other modes. Necessary research would include specialized surveys to examine anglers' species preferences, *WTP* for different mixes of species, and demand for species variety. An example of this type of work was the 2003 Southeast Conjoint Survey add-on to the MRFSS (Gentner 2004). Results from the survey were used to estimate species substitution and changes in value for the red snapper alternatives in the Reef Fish Amendment 27/Shrimp Amendment 14 (GMFMC 2007). Similar work in the future would be facilitated if the specialized surveys were conducted at regular intervals.

Additional information also is needed about the market for for-hire services to enable the replication and expansion of the red grouper case study to other time periods and areas. Specifically, an ongoing data collection of for-hire service fees along with corresponding trip information would be especially useful at characterizing supply and demand in this industry.

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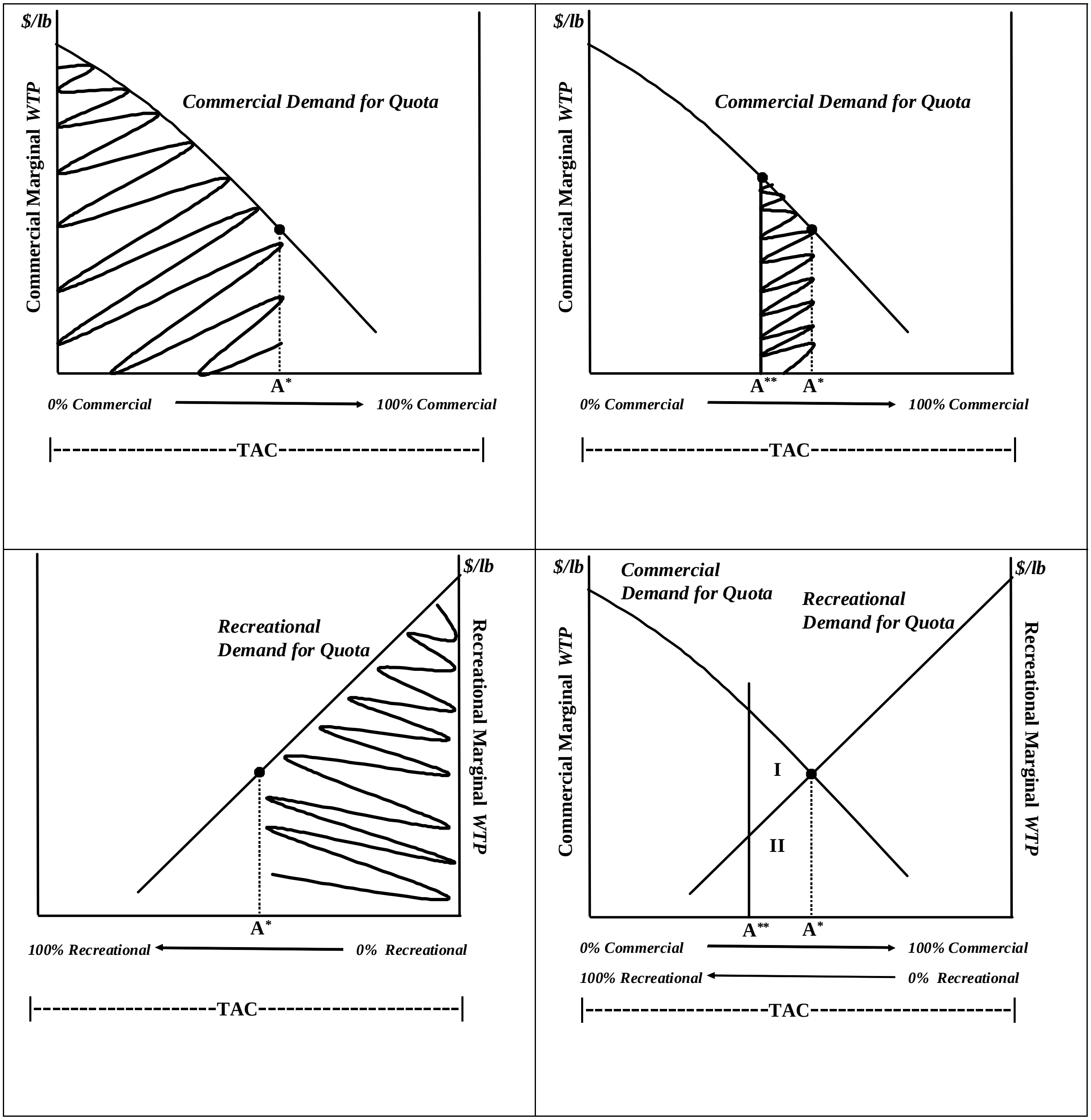

Figure 1. Illustration of Fishery Economics and Allocation Principles

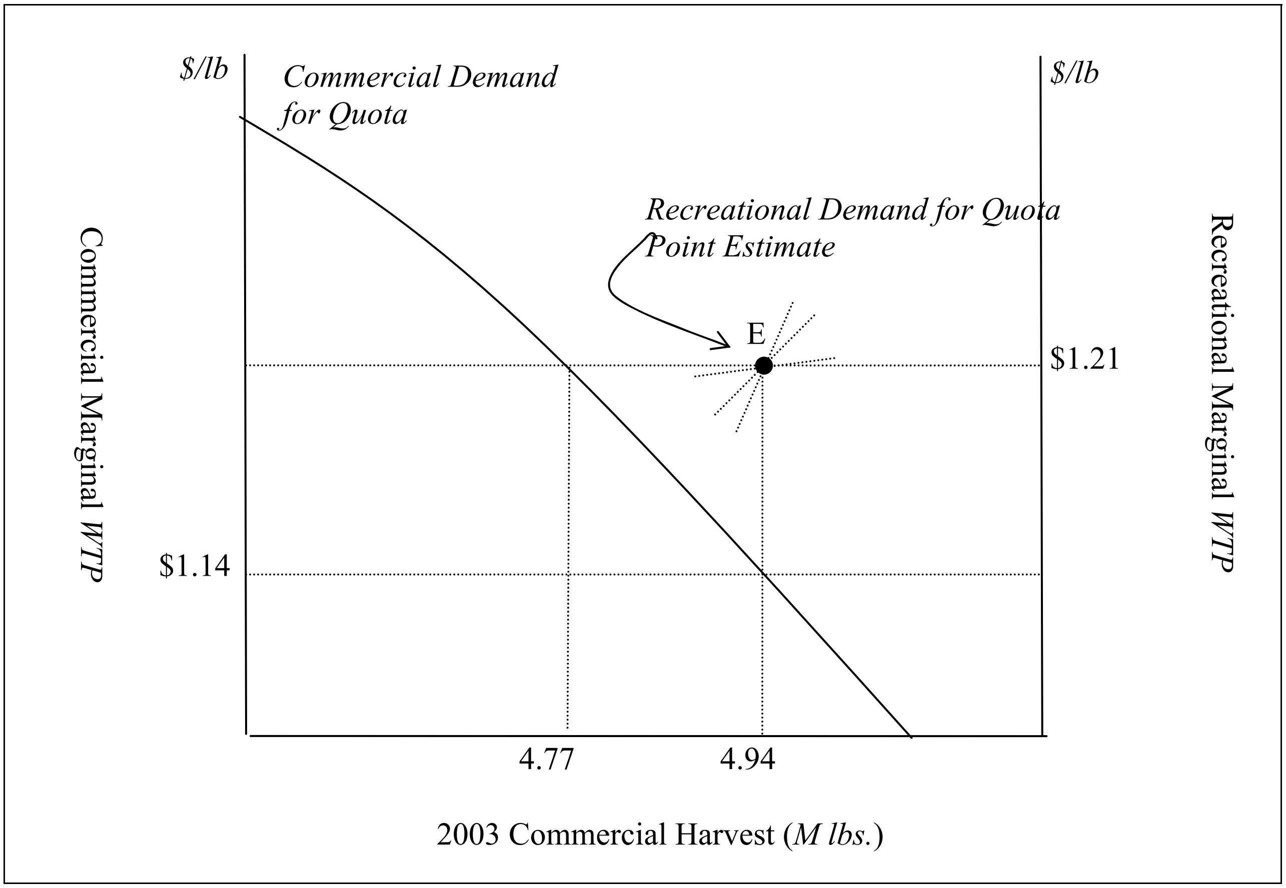

Figure 2. Efficiency of Allocation in 2003

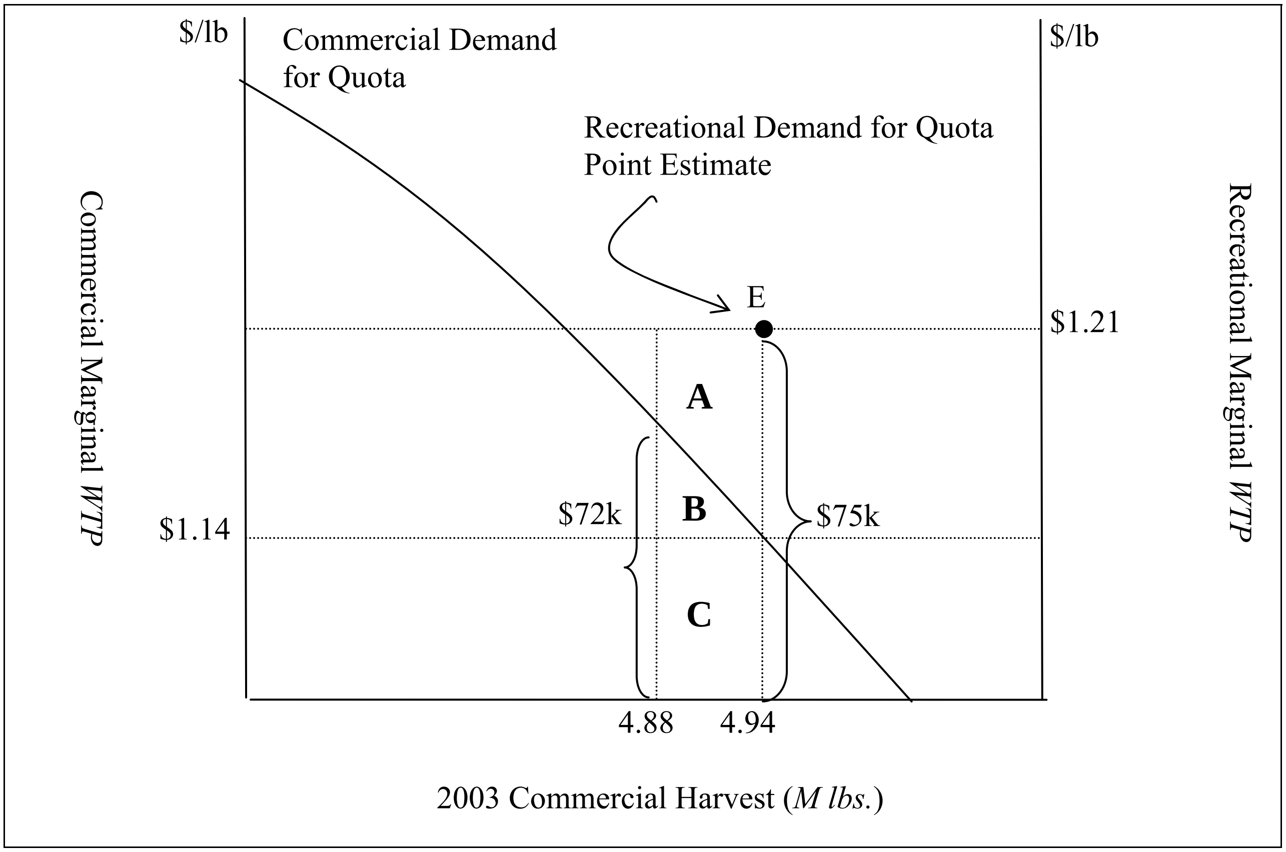

Figure 3. Value of One Percent Re-Allocation from Commercial to Recreational in 2003

Appendix 1: Modeling the Economic Value of Red Grouper to the Commercial Sector

1. Introduction

The Gulf of Mexico Fishery Management Council is revisiting the current allocation of red grouper among the commercial and recreational sectors because of the growing competition for seafood and sport fishing opportunities. According to the *equi-marginal* principle, an economically efficient allocation requires that the marginal value afforded to one sector must equal the marginal value lost by the other sector resulting from the redistribution. In the case of multispecies fisheries, assessing the value of a resource is complex because the value to commercial fishermen is based on profits whereas the value to recreational fishermen is derived from the quality of the recreational experience. Furthermore, the value of one species may be influenced by the value of other jointly-caught species since harvest restrictions on one species may reduce the overall value of the product mix due to complementary and substitution effects in the production process

The objective of this paper is to present an economic framework that values the individual contribution of a single species to the harvest mix while explicitly recognizing the limited selectivity of commercial multiproduct firms. The Gulf of Mexico red grouper resource is used as a case study. The paper is organized as follows. Section 2 provides a brief overview of the regulatory history, section 3 introduces a framework for assessing the economic benefits provided by the commercial sector, and section 4 describes the empirical model and the data sources available for the analysis. The fifth section presents the econometric results and the sixth section introduces the allocation simulation model and results. The last section presents the discussion and main conclusions of this work.

2. Regulatory history

The shallow water grouper complex occurs primarily in the eastern Gulf of Mexico. Red, gag, black, scamp, yellowfin, yellowmouth, rock hind, and red hind grouper comprise the shallow-water grouper complex.[13] Their affinity for reef and hard bottom areas makes them susceptible to fixed gears such as longlines, vertical lines, and traps (Moe 1969; Bullock and Smith 1991). Red grouper is the most important component of the shallow-water grouper complex, followed by gag and black grouper. In 2004, the commercial fleet landed about 10.3 million pounds of shallow water groupers (whole weight) with a dockside value of $22.1 million dollars. Red grouper accounted for 65.8% of the landings and 60.2% of the revenues, and gag accounted for 29.6% of the landings and 34.5% of the revenues. Black grouper accounted for approximately 5% of the landings and revenues. Longlines alone accounted for about 60% of the total red grouper landings. Vertical line and traps were responsible for about 25% and 13% of red grouper landings, respectively.

Federal and state agencies share the responsibility for managing the shallow water grouper complex. In 1984, the Gulf of Mexico Fishery Management Council (GMFMC) implemented the Fishery Management Plan for the Reef Fish Resources (FMP) to protect and rebuild declining reef fish stocks.[14] This FMP banned the use of fish traps, roller trawls and powerhead-equipped spear guns within sensitive inshore areas and mandated the National Marine Fisheries Service (NMFS) to develop a data reporting requirement for the fishery. In 1990, Amendment 1 established that reef fish stocks should achieve a 20% spawning stock biomass per recruit by January 2000. To achieve this goal, the GMFMC set a 20-inch total length

[13] The deep-water grouper complex consists of snowy, yellowedge, speckled hind, warsaw, and misty grouper. The harvesting of Nassau and goliath grouper is banned.

[14] Florida's Marine Fisheries Commission (FMFC) is responsible for managing reef-fish resources within state waters. In 1985, it established a minimum size limit of 18 inches total length for red, gag, yellowfin, Nassau and Goliath grouper.

minimum size limit on red, gag, black, yellowfin and Nassau groupers, and instituted an 11 million pound grouper quota, which was subdivided into a 9.2 million pound shallow-water grouper and 1.8 million pound deep-water grouper quota. In addition, the amendment imposed geographic restrictions where longline and buoy gears could operate, and established reef fish vessel permits and fish trap permits. A maximum of 100 traps per permit holder was allowed.

In 1992, Amendment 4 established a moratorium on the issuance of new reef fish permits for a maximum of three years to stabilize fishing effort while the Council considered a more extensive effort control mechanism. This amendment allowed permit transfers between vessels owned by the same permit holder, and between owners when the permitted vessel was transferred.

In 1996, the U.S. Congress, concerned about the health of the nation's fisheries, passed the Sustainable Fisheries Act (SFA). The SFA mandated that harvest rates be commensurate with the biological productivity of the stocks. SFA required fishery managers to rebuild all over-fished fisheries and capped fishery harvests at the maximum sustainable level. The Act also mandated the assessment and the mitigation, to the extent practicable, of bycatch and bycatch mortality. In addition, the SFA required that essential fish habitat (EFH) be defined and protected. Regulatory protection of EFH resulted in the regulatory amendment of 2000, which afforded greater protection to reef-fish stocks, including shallow-water grouper complex species. Specifically, the regulatory amendment mandated an increase in the minimum total length limit of gag from 20 to 24 inches; prohibited the harvest and sale of red, gag, black grouper between February 15 and March 15 during the peak of the gag grouper spawning season; and established two marine reserves to protect reef fish spawning aggregations.

In October 2000, NOAA declared the red grouper resource to be overfished and undergoing overfishing, which resulted in the development of Secretarial Amendment 1. Secretarial Amendment 1 became effective in July 2004 and established a rebuilding plan for red grouper that relied on a two-tiered commercial shallow water grouper quota. Under the two-tiered quota system, the shallow water grouper fishery (which includes red grouper) would close when either the aggregate shallow-water grouper quota of 8.8 million pounds, gutted weight, or the red grouper quota of 5.31 million pounds, gutted weight, was reached.[15] In addition, it established a commercial quota of 1.02 million pounds, gutted weight, for the deep-water groupers and a commercial quota of 0.44 million pounds, gutted weight, for tilefish.

Following the implementation of the two-tiered quota system, fishing seasons for both shallow and deep-water groupers became shorter. For instance, in 2005, the shallow water grouper fishery was closed on October 10, whereas in 2004 it was closed on November 15. Similarly, in 2005, the deep-water grouper fishery was closed on June 23, while in 2004 it was closed on July 15. Concerns about the adverse social and economic impacts of progressively shorter fishing seasons and derby-style fishing led to the implementation of an emergency rule on March 3, 2005. Under this emergency rule, a commercial trip limit of 10,000 pounds, gutted weight, was implemented for deep-water groupers and shallow water groupers combined. This initial 10,000 pound trip limit was subsequently reduced to 5,500 lbs depending on the season and quota utilization thresholds.

The interim stepped-down trip limit system was phased out in January 2006, when a regulatory amendment established a permanent, aggregate shallow-water and deep-water grouper

[15] The State of Florida automatically closes the red grouper fishery in state waters when federal closures occur.

trip limit of 6,000 pounds, gutted weight. On February 7, 2007, the use of fish traps in the Gulf reef fishery was prohibited.

Presently, the GMFMC is considering a new amendment to the reef-fish fishery management plan. An important component of this amendment is the development of a multispecies individual transferable quota program to provide the opportunity for a year around fishery, enhance business planning and financial stability and promote safe fishing operations.

3. Conceptual model

Harvesting sub-sector

The limited ability of multispecies fishing firms to control their catch composition makes the valuation of the red grouper resource a complex undertaking. Intricate substitution and complementary interrelationships, which bound multiproduct fishing firms' production choices, obscure the contribution of each species to the overall welfare. To unravel these interrelationships and value the species specific contribution to the fishery's welfare, we develop a model that assumes that the longline and vertical line fleets are composed of profit maximizing multioutput (multispecies) firms and that each firm's indirect short-run, trip-level profit function is given by

$$(1) \qquad \pi(p,w;K)=\sum_{i=1}^{n}p_i y_i(p,w;K)-\sum_{j=1}^{m}w_j x_j(p,w;K)$$

where π is the restricted (short-run) profit function, p_i is the dockside price of species i, y_i is harvest of species i, w_j is the price of input j, and x_j is the amount of input j used. K is the quasi-fixed capital stock. As is customary in production analysis, we presume that the profit function is non-decreasing in output prices and fixed factors, non-increasing in input prices, linear homogenous and convex in prices, concave in fixed quantities, and continuous and twice differentiable.

The restricted profit function measures quasi-rent. Quasi-rent is the payment to factors of production which are temporarily in fixed supply. The short-run nature of the model is not only conditional on the quasi-fixed capital stock, but also is conditional on the available fish biomass. Thus, changes in the capital stock and resource biomass will influence the profitability of the industry.

Output supply and factor demand functions are obtained via Hotelling's lemma,

$$\text{(2)} \qquad \frac{d\pi(p,w;K)}{dp_i} = y_i(p,w;K)$$

$$\text{(3)} \qquad \frac{d\pi(p,w;K)}{dw_j} = -x_j(p,w;K)$$

These supply and demand functions describe the optimal adjustment of outputs and inputs in response to changes in output and input prices, given the fixed input.

Since the basic tenet of economic efficiency compares the benefits and costs of redistributing the red grouper quota at the margin, it is instructive to consider how a multiproduct fishing firm's willingness to pay for red grouper quota changes as a function of the quota available. Fulginiti and Perrin (1993) describe the relationship between a quota-constrained quasi-rent function and an unconstrained quasi-rent function using the concept of virtual price. Virtual price, p_v, is the price that would induce an firm to freely produce at the desired quota level. Formally,

$$\text{(4)} \qquad \frac{\partial \pi}{\partial p_{v_1}} = \overline{q}_1$$

Mathematically, the virtual price is given as

$$\text{(5)} \qquad p_{v_1} = (p_1 - \lambda_1)$$

where p_1 is the output price and λ_1 is the rent per unit of red grouper quota (output 1). Lambda expresses the marginal valuation of output 1. At the virtual price for quota 1, the quota quasi-rent function must equal the quota-free quasi-rent function

(6) $$\pi(p_1, p_h, w; \bar{q}_1, K) = \pi(p_v, p_h, w; K)$$

where p_h is the *n-1* vector of other output prices.

Alternatively, the quota quasi-rent function can be expressed as

(7) $$\begin{aligned}\pi(p_1, p_h, w; \bar{q}_1, K) &= \pi(p_v, p_h, w; K) + (p_1 - p_v)\ \bar{q}_1 \\ &= \pi(p_1 - \lambda_1, p_h, w; K) + \lambda_1\ \bar{q}_1\end{aligned}$$

Rewriting (7) we get

(8) $$\pi(p, w; \bar{q}_1, K) = \sum_{i=2}^{n} p_i y_i (p_1 - \lambda_1, p_h, w; K) + \lambda_1\ \bar{q}_1 - \sum_{j=1}^{m} w_j x_j (p_1 - \lambda_1, p_h, w; K)$$

Applying Hotelling's lemma, we get the output and input functions

(9) $$\frac{\partial \pi}{\partial p_i} = y_i (p_1 - \lambda_1, p_h, w; K)\ \forall \text{ i } \geq 2$$

(10) $$\frac{\partial \pi}{\partial w_j} = -x_j (p_1 - \lambda_1, p_h, w; K)$$

Differentiating equation (8) with respect to quota 1 levels, we obtain the inverse derived demand for quota. The difference between market output price and the virtual price is the quota rent.

(11) $$\frac{\partial \pi}{\partial \bar{q}_1} = \lambda_1 (p, w; \bar{q}_1, K)$$

The firm's inverse derived demand for quota captures the optimal adjustment in inputs used and other outputs as the quota changes. It indicates by how much a firm's implicit marginal valuation of quota must change for a vessel to want to hold an additional unit of quota (Squires and Kirkley, 1996; Just et al, 2004). Drawing on the inverse derived demand for quota relationship, we can estimate the quasi-rent in either output or input space as quota becomes binding. Using equation (9), we can estimate the producer surplus (and quasi-rent) in output space

$$PS = \int_{p_1^0}^{p_1-\lambda_1} \frac{\partial \pi}{\partial p_1}(p,w;K)dp_1 + \int_{p_1-\lambda_1}^{p_1} \overline{q}_1 dp_1 = \int_{p_1^0}^{p_1-\lambda_1} y_1(p,w;K)dp_1 + \int_{p_1-\lambda_1}^{p_1} \overline{q}_1 dp_1$$

(12) $$= \pi(p_1-\lambda_1, p_h, w; K) + \lambda_1 \overline{q}_1 = \pi(p,w;\overline{q}_1,K)$$

where p^0_1 is the price that causes the firm to cease production (Vestergaard, 1999). Figure I.1 shows the producer surplus in the output market. The producer surplus is the sum of the harvest surplus (area A) and quota surplus (area B). Mathematically, the harvest surplus and quota surplus can be calculated by solving the first and second integral of equation (12), respectively.

Alternatively, we can also calculate changes in quasi-rent in input space. The area under the implicit derived demand for quota up to the quota level can be used to measure quasi-rent (Figure I.2). The producer surplus is the sum of the harvest surplus (area C) and quota surplus (area D). This is true, because the inverse derived demand for quota reflects the firm's valuation of quota as the quota level varies.

(13) $$PS = \int_0^{\overline{q}_1} \lambda_1(p,w;\overline{q}_1,K)dy_1 = \int_0^{\overline{q}_1} \frac{\partial \pi}{\partial \overline{q}_1} dy_1 = \pi(p,w;\overline{q}_1,K)$$

To derive the commercial sector's demand curve for quota we simply horizontally sum individual, trip-level demand curves. The commercial sector's rental price of the last unit of quota is determined by the intersection of the sector's derived demand for quota with the perfectly inelastic supply curve for quota. Changes in producer surplus or quasi-rents can be estimated as described above by integrating under different levels for the total allowable commercial catch (TACC).

Consumer sub-sector

Catch restrictions not only impact the profitability of harvesters, but also impact consumers who pay higher seafood prices. Hence, changes in consumer surplus must be considered when redistributing the TAC between the commercial and recreational sectors. Ideally, we would have estimated a retail level demand curve, but data limitations forced us to estimate a wholesale demand curve instead. We assumed the wholesale demand curve to be a function of prices of complements and substitutes, disposable income, population size, and red grouper landings.

(14) $$P_{redgrouper} = f(P_{complements}, P_{substitutes}, Income, Population\ size, Own\ landings \mid TACC)$$

Potential substitutes for red grouper included other domestic species such as other shallow water groupers, snappers, mahi-mahi and fresh and frozen grouper imports.

4. Empirical Model

Harvesting sub-sector

Following Squires and Kirkley (1991), we presume that fishermen maximize profits in two stages. In the short-run, fishermen advance their welfare by catching the species mix that maximizes revenues conditional on existing fixed factors, weather, habitat and resource abundance and relative output prices. In other words, we assume that revenue maximization is an appropriate behavioral hypothesis since fishing vessels cannot readily change input levels during the harvesting process. Furthermore, we lacked data on harvesting cost. In a second stage, fishermen maximize long-term profits by selecting the optimal capital endowment.

This study focuses on the short-run fishing behavior. It assumes that vertical line and longline vessels maximize short-run, trip-level revenues by selecting the optimal species composition and catch level conditional upon quasi-fixed factors (Kirkley and Strand, 1988;

Squires and Kirkley, 1991). The vertical line gear encompasses both handline and bandit gear vessels. We adopt the non-homothetic generalized Leontief quasi-rent function, which is given by

$$(15) \qquad \pi(p;K) = \sum_{i=1}^{n} \alpha_i p_i K^2 + \sum_{i=1}^{n} \beta_{ij} (p_i p_j)^{1/2} K$$

where π is the quasi-rent function, K is the quasi-fixed input, and p_i is the output price of species i. Symmetry is imposed by setting $\beta_{ij}=\beta_{ji}$ for $i\neq j$. Although there are several flexible functional forms available to approximate fishermen's revenue function, we selected the non-homothetic generalized Leontief functional form because it places few restrictions on the underlying structure of the technology and permits the examination of important properties such as separability and non-jointness.[16] Another consideration was that this functional form permits the estimation of output levels rather than output shares like in the case of the translog functional form (Kirkley and Strand, 1988). Modeling output levels rather than shares is appealing because it is more intuitive to decision-makers and readily lends itself to the estimation of a derived demand for red grouper quota.

Applying Hotelling's lemma, we obtain the associated input-compensated, unconstrained supply equations,

$$(16) \qquad \frac{\partial \pi}{\partial p_i} = y_i = \alpha_i K^2 + \beta_{ii} K + \sum_{j \neq i} \beta_{ij} \left(\frac{p_j}{p_i}\right)^{1/2} K$$

The supply equations are input-compensated because they are conditional on the fixed input.

[16] However, this functional form imposes linear homogeneity in prices (Kirkley and Strand, 1988).

To investigate the welfare changes of introducing a TACC for red grouper, we horizontally summed all the trip-level, derived demand curves for the various fleets to construct an aggregate, commercial sector-wide derived demand for quota.

Estimation:

We specified the non-homothetic generalized Leontief revenue function as

(17)

$$\pi(p;K) = \sum_i \alpha_i p_i K^2 + \sum_i \sum_j \beta_{ij} (p_i p_j)^{1/2} K + \sum_i \sum_k \delta_{ik} d_k p_i K + \sum_i \sum_l \varepsilon_{il} e_l p_i K + \sum_i \sum_m \phi_{im} f_m p_i K + \sum_i \sum_k \chi_{iz} c_z p_i K + \sum_i \sum_n \varphi_{in} g_n p_i K + \sum_i \sum_o \gamma_{io} h_o p_i K + \sum_i \sum_r \eta_{ir} l_r p_i K + \sum_i \sum_s \kappa_{is} t_s p_i K + \sum_i \sum_u \varpi_{iu} v_u p_i K$$

where $\pi(p; K)$ is the quasi-rent function, K is the quasi-fixed input, and p_i is the output price of species i. d_k is the k^{th} of eleven binary variables for months February-December, and e_l is the l^{th} of two binary variables for years 2002 and 2003. f_m is the m^{th} binary variable for landing county: Bay, Citrus, Franklin, Lee, Escambia, Monroe, Pinellas, Okaloosa and Wakulla counties for the vertical line fleet and Bay, Manatee, Monroe and Pinellas counties for the longline fleet. C_z is the z^{th} binary variable for fishing ground. The binary variables for month, year and fishing grounds control for changes in the availability and abundance of the targeted stocks. t_s is the monthly accumulated cyclonic energy (ACE) index, which captures intensity and duration of Atlantic named storms and hurricanes occurring during a given season,[17] and v_u is a dichotomous variable for the vertical line fleet only; it takes the value a 1 if bandit gear is used and zero otherwise (i.e., handline gear is used). The year 2003 was used as the base year.

[17] Formally, the ACE index equals the sum of the squares of the maximum sustained surface wind speed (knots) measured every six hours for all named systems while they are at least tropical storm strength.

G_n, h_o, and l_r are dichotomous variables that capture the presence of three closures. The g_n captures the annual closed season from February 15 through March 15, which has been in effect since 2000 for red, gag, and black grouper. The second closure variable, h_o, captures the closure of shallow water grouper and red grouper fishery on November 15, 2004. The third closure variable captures the closure of the deep-water grouper fishery on July 15, 2004. These closures take a value of 1 when active. The number of days away from port is set as the quasi-fixed input since during the fishing trip capital and labor are effectively fixed.[18] Symmetry was imposed by setting $\beta_{ij}=\beta_{ji}$ for $i\neq j$.

Applying Hotelling's lemma, we obtain the associated input-compensated supply equations

(18) $$\frac{\partial \pi(p;K)}{\partial p_i} = q_i = \alpha_i K^2 + \beta_{ii} K + \sum_{j\neq i} \beta_{ij} (\frac{p_j}{p_i})^{1/2} K + \rho\, K$$

where

$$\rho = \sum_k \delta_{ik} d_k + \sum_l \varepsilon_{il} e_l + \sum_m \chi_{iz} c_z + \sum_m \phi_{im} f_m + \sum_n \varphi_{in} g_n + \sum_o \gamma_{io} h_o + \sum_r \eta_{ir} l_r + \sum_s \kappa_{is} t_s + \sum_u \omega_{iu} v_u$$

The demand for red grouper quota can be derived from the estimated unconstrained output supply equations using the virtual price framework (Fulginiti and Perrin, 1993). Virtual prices allow us to relate the properties of unconstrained output supply and factor demand functions to those properties of rationed functions when these are evaluated at the virtual prices.

[18] Traditionally, studies have used days absent times grt (or days at sea times other vessel characteristics such as vessel length) as proxy for a quasi-fixed factor. However, we selected days absent alone since information about vessel characteristics, particularly for longliners, was far from complete and severely reduced the number of observations available for estimation. Thus, we opted to use days absent alone since the larger number of observations available for use would provide us with better econometric results.

Substituting the red grouper ex-vessel price by its virtual price in equation (18), we obtain the firm's inverse derived demand for quota

$$(19) \qquad \lambda_1 = p_1 - \left\{ \frac{K \sum_{j \neq 1} \alpha_{1j} p_j^{0.5}}{\overline{q}_1 - \alpha_1 K^2 - \beta_{11} K - \rho K} \right\}^2$$

where λ_1 is the firm-level, input-compensated unit rent of quota, p_1 is the red grouper ex-vessel price, $\overline{q}_1$ is for red grouper quota, and squared term of equation (19) is the virtual price. The value of λ_1 becomes larger as the quota becomes binding (otherwise it takes a value of zero). The firm's inverse derived demand for quota shows the firm's implicit marginal valuation of quota. It states by how much the implicit marginal valuation must change to encourage firms to lease an additional unit of quota (Squires and Kirkley, 1996).

To simulate the quota market for red grouper, trip-level derived demand curves are horizontally summed.[19] The market equilibrium lease price is found by equating the market demand with the TAC. In the single quota case with overall quota of $\overline{Q}_1$, the equilibrium ITQ market is

$$(20) \qquad \overline{Q}_1 = \sum_k \left\{ \alpha_1 (K^k)^2 + \beta_{11} K^k + \sum_{j \neq 1} \beta_{1j} \left[\frac{p_j^k}{(p_1^k - \lambda_1^k)} \right]^{0.5} K + \rho K^k \right\}$$

where k are the number of trips.

Data:

Landings and effort data for the vertical line and longline vessels that landed red grouper on the west coast of Florida were obtained from Florida's Department of Natural Resources. The State

[19] Because our analysis only included well-behaved observations, there was a shortage between our model landings and the official landings. To address this landings deficit, we randomly selected additional trips (i.e., some trips were counted twice) for use in the analysis so that landings exhausted the TAC.

of Florida requires commercial fishermen to complete a trip ticket every time they take a fishing trip and sell their catch to a dealer. Florida's Marine Fisheries Trip Ticket database contains information about landings and prices by species, area fished, county of landing, and gear-specific fishing effort. Landings from the vertical line fleet, were grouped into four categories: red grouper, other shallow-water groupers, shallow and mid-water snappers and a residual or miscellaneous group, which captured all species not included in the earlier groupings. Similarly, landings from the longline fleet were assembled into three groupings: red grouper, other shallow water groupers, and a miscellaneous group. We used Trip ticket data from 2002 to 2004. Descriptive statistics for the vertical line and longline fleets are presented in Tables I.1 and I.2.

<u>Consumer sub-sector</u>

We estimated a linear, annual demand curve for the wholesale prices as a function of disposable income, fresh grouper imports (substitute), and Gulf of Mexico landings. Mathematically, the wholesale demand function is given by

$$(21) \qquad P_{redgrouper} = f(Disposible\ Income, P_{substitutes}, Fleet\ own\ landings)$$

Data:

Disposable income, population size, and consumer price index data were obtained from the Bureau of Labor Statistics (BLS) and Bureau of Economic Analysis (BEA).[20] Wholesale prices from the Fulton Market, dockside prices and landings of substitutes and complements were obtained from NOAA Fisheries website. Information on fresh and frozen imports originally came from the Foreign Trade Division of the U.S. Census Bureau. Table I.3 shows descriptive statistics of the variables used in this model.

5. Econometric Results

Harvesting sub-sector:

We estimated individual equations separately using ordinary least squares (OLS) and tested for heteroscedasticity using White's test. Based on earlier production work with this specification, we anticipated that heteroscedasticity would be introduced by the square of the quasi-fixed input variable (Squires and Kirkley, 1991; Campbell and Nicholl, 1994) so we weighted the sample by the quasi-fixed input. This addressed the heteroscedasticity present in the equations for red grouper and other shallow water groupers in the longline model, but it failed to remove any of the heteroscedasticity present in the vertical line model. Given the above and the utility of standardizing both models, we estimated input-scaled output supply functions for both the longline and vertical line fleets using full information maximum likelihood estimator (Greene, 2000).[21] The generalized R^2 for the system of equations prior to the correction for heteroscedascity was 79.6% for the vertical line and 57.6% for the longline fleet.

[20] See, http://www.bls.gov/cpi/home.htm , http://www.bea.gov/national/nipaweb/Index.asp, and http://www.st.nmfs.gov/st1/market_news/index.html

[21] The functional form was presumed to be exact rather than an approximation. We also assumed that the errors are from optimization rather than approximation and applied only to the input-scaled supply equations (Squires and Kirkley, 1991). The issue of zero outputs came up in some instances, creating a

Table I.4 shows that yearly, monthly, fishing ground and closure variables, as a group, are statistically significant for the vertical line fleet. Table I.5 shows that yearly, monthly, fishing ground and closure variables, as a group, are statistically significant for the longline fleet.

Table I.6 presents hypothesis tests about the underlying harvesting technology. The hypotheses of input and output separability and overall non-jointness-in-inputs were rejected for both the longline and vertical line fleets. The rejection of input-output separability implies that there are specific interactions between input and output combinations. Therefore, changes in relative prices can influence the optimal combinations of capital and labor devoted to the harvesting process. The rejection of input-output separability also implies that the technology does not allow for the creation of a single composite input and single composite output. Thus, fishery managers should consider management measures that require species-specific (or species groups) quotas rather than a single aggregate quota for all species.

The rejection of overall non-jointness-in-inputs indicates that all inputs are required to produce all outputs. It also indicates that the harvesting process is interrelated. Hence, each species' production process cannot be regulated independently because of the presence of spillover effects on other species. For instance, establishing a quota for any of these individual species may lead to the overexploitation of an unregulated substitute species. If the harvesting process was not joint-in-inputs then single species would be appropriate since regulations would not impact the production process of the other species. Species-specific non-jointness-in-inputs was rejected for all species, except for the other shallow-water groupers for the longline fleet.

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limited-dependent variable problem, which can introduce bias and non-normality of the residuals. The procedure of Lee and Pitt (1987) addresses this issue using virtual prices, but it is not computationally feasible with the number of variables in this study (Squires and Kirkley, 1991). A Box-Cox transformation could be used, but we decided against it because a particular form of non-normal disturbances is assumed prior to transformation (Squires and Kirkley, 1991). Thus, we substituted a value of 0.1 for zero when necessary.

The rejection of species-specific non-jointness-in-inputs indicates that the production of any given species is affected by the relative prices and quotas of the other jointly-caught species.

This study also examined own-price and cross price elasticities of supply. Price elasticities of supply measure the responsiveness of the quantity supplied due to a change in price. The diagonal elements in Tables I.7 and I.8 represent the own-price elasticities, and the off-diagonal elements represent the cross-price elasticities. The mixed pattern of complementarity and substitutability suggests that single species management may have unintended consequences on the rest of the fishery. All own-price elasticities for the vertical line and longline fleets were positive; however, they were statistically different than zero only for other shallow-water grouper, shallow and mid-water snapper, and miscellaneous species groupings in the vertical line fleet. The residual species group had the only statistically significant own-price elasticity for the longline fleet. In both the vertical line and longline fleets, the residual group was found to be a statistically significant substitute for red grouper. Thus, if managers imposed a quota on red grouper, fishermen would be able to adjust their catch mix by landing more of the miscellaneous species. Scale elasticities for the vertical line fleet were positive and statistically significant for the shallow water grouper and miscellaneous species groupings. All scale elasticities were positive and statistically significant for the longline fleet.

<u>Consumer sub-sector:</u>

We attempted to estimate a linear annual demand curve for red grouper wholesale prices as a function of disposable income, Gulf of Mexico landings and fresh grouper imports. We tried an annual model rather than monthly model to make it easier to examine welfare changes due to annual quotas. Unfortunately, because we don't have a long time series of seafood imports, this severely limited our ability to incorporate as many explanatory variables as we had hoped.

The estimation was conducted in two steps. First, we regressed monthly red grouper wholesale prices (using NOAA prices from Fulton Market) against Gulf of Mexico red grouper ex-vessel prices and found that without intercept, the slope was 1.61 suggesting a 61% mark-up for whole fish. Second, because we wanted to estimate an annual welfare loss from reducing the red grouper commercial quota, we regressed imputed annual wholesale prices (i.e., ex-vessel prices times 1.61) against disposable income, prices for fresh imported groupers, and Gulf of Mexico red grouper landings using OLS. Parameter estimates are shown in Table I.9. The equation was statistically significant at the 0.05 level (F-value was 5.26). The adjusted R^2 for this regression was 48%. Examination of the parameter estimates shows that none of them were statistically significant, suggesting that red grouper price flexibilities are inelastic.

6. Simulation

A simple simulation model to estimate the commercial sector's willingness to pay for red grouper quota was undertaken as follows. We started by horizontally summing each vessel's unconstrained, trip-level red grouper supply equation to obtain an unconstrained, annual red grouper supply per vessel. Then, we substituted the ex-vessel red grouper price by its virtual price ($p_v = (p_1 - \lambda_1)$) since virtual prices permit us to relate unconstrained output supply functions to constrained output supply functions when these are evaluated at the virtual prices. Next, we traced the annual supply function by vessel by raising the rental price of quota (λ_1) from $0 to $4 per lb. Finally, we horizontally summed the annual, vessel-level derived demands for quota from the longline and vertical line fleets to solve an industry derived demand for red grouper quota.[22] Figure I.3 shows how the commercial sector's willingness to pay for red

[22] We based our analysis on 2003 data because fishermen's production process was not influenced by trip limits (and potential discarding). Although, the trap sector was active in 2003, we did not include it in this

grouper quota (or marginal benefit, $/lb of whole weight) as a function of the quota available to this sector. The willingness to pay per pound of red grouper quota ranges from $0 to $3.38.

Table I.10 illustrates the marginal benefit and quasi-rent assuming that the commercial sector is capable and willing to harvest the entire TAC (i.e., 6.5 million pounds of gutted weight).This Table shows that as the commercial allocation decreases, the price per pound that the commercial sector is willing to pay for additional quota increases, but their total benefits decline. When the commercial sector receives approximately 6.5 m lbs of gutted weight, the marginal benefit is zero and the quasi-rent is $10.2 million, as measured by the area under the commercial sector's derived demand between 0 and 6.5 m lbs. At the 2003 allocation of 5.31 m lbs, the willingness to pay for red grouper quota is $0.95 per pound and the quasi-rent is $9.58 million. If the commercial sector receives 5.0 m. lbs of gutted weight, then the willingness to pay for quota increases to $1.11 per pound and the quasi-rent equals $ 9.258 million.

7. Discussion and Conclusion

This paper had two main objectives. The first objective was to develop a conceptual framework to assess the species-specific contribution to the overall value of the catch of a multiproduct fishing firm while explicitly recognizing the existing technological interactions which bound these firms' selectivity. The second objective was to develop an applied model to estimate the commercial harvesting sector's willingness to pay for Gulf of Mexico red grouper quota. As expected, the econometric analysis showed that the vertical line and longline technologies were joint-in-inputs, which indicates the presence of technological

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simulation since this gear is currently banned in Gulf waters. Nevertheless, we expect trap fishermen to continue fishing with legal vertical lines or longlines. Therefore, we randomly selected additional vertical line and longline trips (i.e., some trips were counted twice) in the computation of the derived demand for red grouper quota until the predicted landings from these two gears exhausted the TAC when $\lambda=0$.

interrelationships. The presence of jointness-in-inputs technologies also indicated that the commercial harvesting sector had limited control over the catch composition. Drawing on the econometric estimates, we estimated that the commercial harvesting sector's maximum willingness to pay for quota would be $3.38 per pound. At the 2003 allocation of 5.31 m. lbs gutted weight, the willingness to pay for quota decreases to $0.95 per pound and the quasi-rent equals $ 9.58 million.

This approach offers valuable insights about allocation issues. First, it provides ex-ante estimates for the commercial harvesting sector's willingness to pay for quota, which could be coupled with willingness to pay estimates from the recreational sector (if available) to determine the economically efficient allocation according to the equi-marginal principle. Second, while economic efficiency may not be the overriding concern of fishery managers, these results can be used to estimate the cost of achieving various social objectives such as preserving coastal communities or family owned businesses. The cost of basing an allocation on a social objective is simply the quasi-rents foregone by not adopting the economically optimal allocation.

Third, while this paper focuses on the allocation between the commercial and recreational interests, this framework could be used to estimate the benefits and costs of intra-sector allocations (e.g., across gear types). The estimated quota prices for each subgroup could allow fishery managers identify the economically efficient gear types and anticipate the distributional impacts of a potential creation of a market for quotas. In the event of the creation of a quota market, the resulting prices for quota will guide the flow of quota across gear types. In general, efficient fishermen will be willing to pay relatively higher prices for quota, while less efficient fishermen will be willing to pay relatively lower prices for quota. Thus, we would expect that efficient fishermen will buy additional quota to increase their quota holdings whereas less efficient fishermen will downsize (or exit altogether) by selling some (or all) of their quota holdings.

Last, fishery managers must be cautioned that the estimated willingness to pay for quota is based on the existing management regime. Hence, if regulations change, or allocation decisions are accompanied by new regulations, then fishery managers must recognize that each sector's willingness to pay for quota likely will change.

8. References

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Figure I.1: Producer surplus in output market.

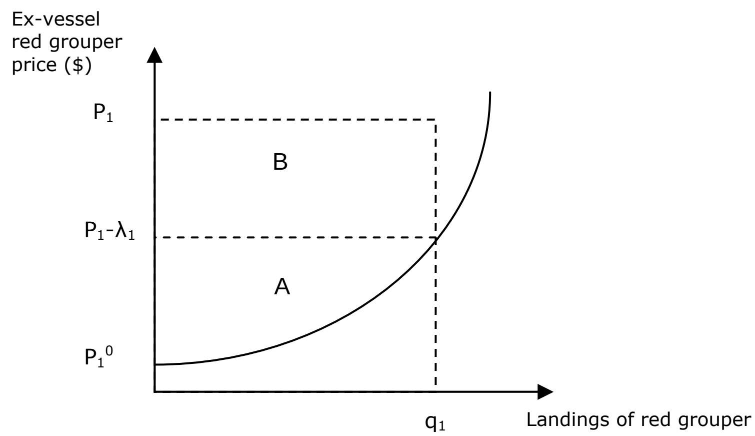

Figure I.2: Producer surplus in input market.

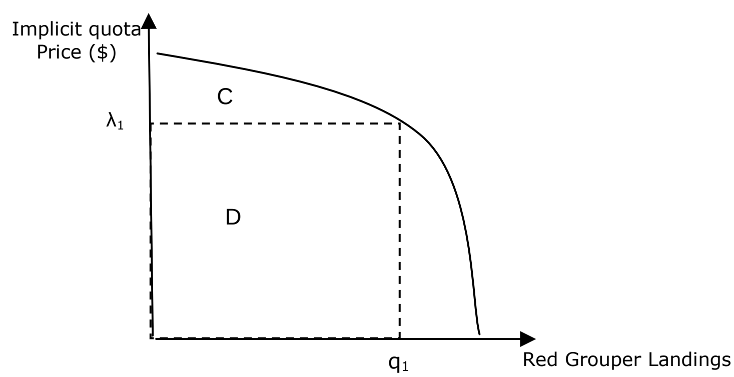

Figure I.3: Marginal Benefit Curve for the Commercial Sector.

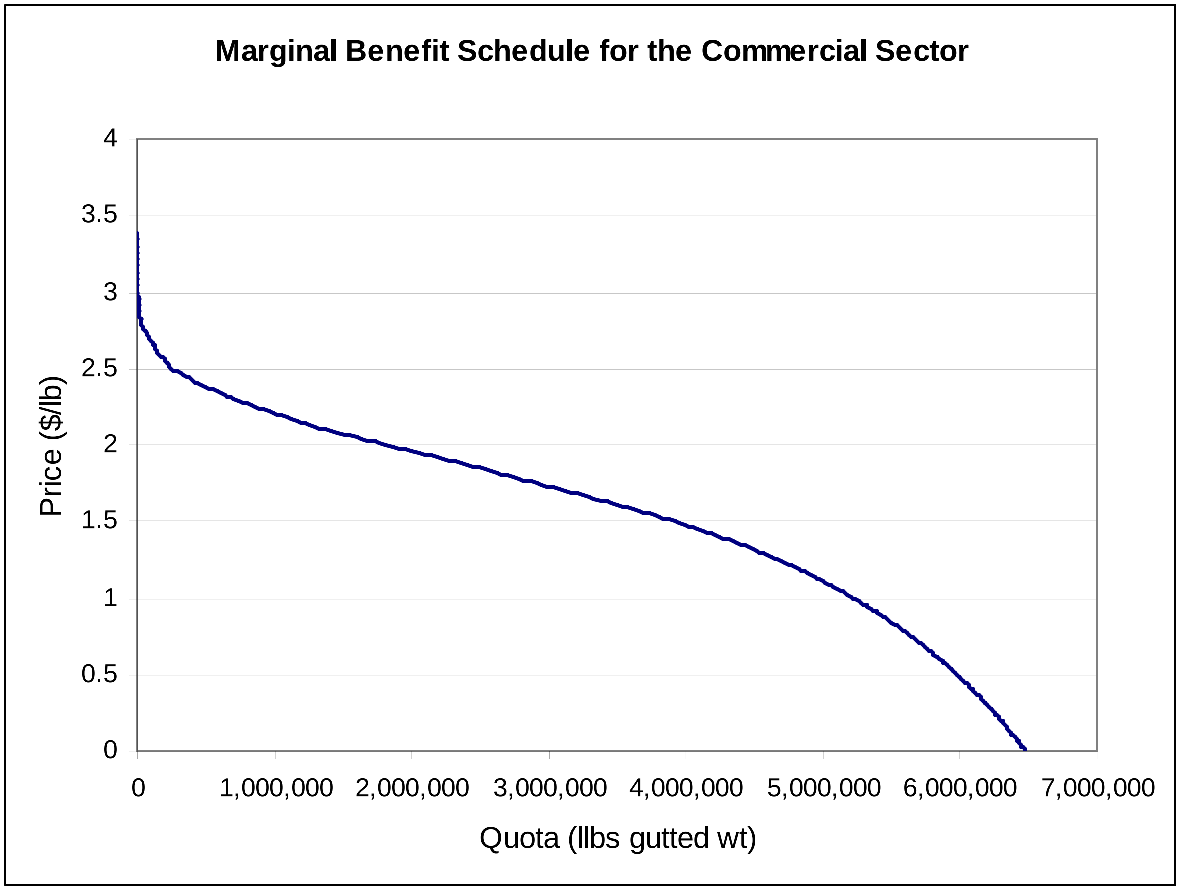

Table I.1: Descriptive statistics for the vertical line fleet, 2002-2004.

Variable	Mean	Std. Dev.	Min	Max	N
Red grouper landings per trip (lbs)	209.11	432.32	0.10	94,89.00	28,770
Other Shallow-water grouper landings per trip (lbs)	229.03	532.15	0.10	11,736.00	28,770
Shallow and mid-water snapper landings per trip (lbs)	317.21	672.77	0.10	7,599.00	28,770
Residual species landings per trip (lbs)	214.59	507.38	0.10	13,752.00	28,770
Price of red grouper ($/lbs)	1.98	0.21	0.42	4.66	28,770
Price of other shallow water grouper ($/lbs)	2.45	0.22	0.51	3.39	28,770
Price of deep-water grouper ($/lbs)	2.00	0.33	0.32	3.68	28,770
Price of residual species group ($/lbs)	1.13	0.37	0.14	4.21	28,770
Quasi-fixed input (days)	3.22	2.49	1.00	30.00	28,770

Table I.2: Descriptive statistics for the longline fleet, 2002-2004.

Variable	Mean	Std. Dev.	Min	Max	N
Red grouper landings per trip (lbs)	2,369.04	2,403.51	0.10	18,836.00	4,335
Shallow-water grouper landings per trip (lbs)	870.03	1,489.09	0.10	13,577.00	4,335
Residual species landings per trip (lbs)	1,111.39	2,159.83	0.10	20,688.00	4,335
Price of red grouper ($/lbs)	2.28	0.25	1.50	3.25	4,335
Price of shallow-water grouper ($/lbs)	2.81	0.29	0.97	3.65	4,335
Price of residual species group ($/lbs)	1.65	0.54	0.21	20.00	4,335
Quasi-fixed input (days)	8.07	4.19	1.00	25.00	4,335

Table I.3: Descriptive statistics for variables used to estimate wholesale demand for red grouper.

Variable	Mean	Std. Dev.	Min	Max	N
Wholesale price of red grouper ($/lbs)	3.51	0.18	3.22	3.93	15
Import price of fresh grouper ($/lbs)	1.32	0.15	1.10	1.57	15
Disposable income ($)	27.67	1.90	25.25	30.53	15
Gulf of Mexico landings (million lbs)	6.18	0.85	4.68	7.52	15

Table I.4: Statistical significance of group dummy variables for the vertical line fleet.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Vertical line	Yearly dummies	166.37	<.0001	Reject null
	Monthly dummies	1332.2	<.0001	Reject null
	Fishing ground dummies	2679.8	<.0001	Reject null
	County landed dummies	9713.6	<.0001	Reject null
	Seasonal closure dummies	722.67	<.0001	Reject null
	Shallow-water grouper closure dummies	192.30	<.0001	Reject null
	Deep-water grouper closure dummies	247.84	<.0001	Reject null
	ACE dummies	1.88	0.7583	Accept null
	Bandit gear dummies	49.07	<.0001	Reject null

Table I.5: Statistical significance of group dummy variables for the longline fleet.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Longline	Yearly dummies	16.71	0.0104	Reject null
	Monthly dummies	95.25	<.0001	Reject null
	Fishing ground dummies	480.03	<.0001	Reject null
	County landed dummies	341.58	<.0001	Reject null
	Seasonal closure dummies	103.62	<.0001	Reject null
	Shallow-water grouper closure dummies	46.05	<.0001	Reject null
	Deep-water grouper closure dummies	19.14	0.0003	Reject null
	ACE dummies	1.00	0.8024	Accept null

Table I.6: Hypothesis tests of the technological structure of the longline and handline fleets.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Vertical line	Input-output separability	285.88	<.0001	Reject null
	Non-jointness in inputs			
	Overall	283.04	<.0001	Reject null
	Red grouper	66.28	<.0001	Reject null
	Shallow-water grouper	146.32	<.0001	Reject null
	Shallow and mid-water snappers	183.72	<.0001	Reject null
	Miscellaneous species	116.19	<.0001	Reject null
Longline	Input-output separability	92.72	<.0001	Reject null
	Non-jointness in inputs			
	Overall	8.78	0.0324	Reject null
	Red grouper	8.41	0.0149	Reject null
	Shallow-water grouper	2.13	0.3441	Accept null
	Miscellaneous species	6.86	0.0324	Reject null

Table I.7: Input-compensated own and cross price and scale elasticities for the vertical line fleet (standard errors in parenthesis)

Prices and effort	Elasticity Red grouper	Shallow-water grouper	Shallow and mid-water snappers	Miscellaneous species
Red grouper	0.06	0.11	0.08	-.26*
	(0.10)	(0.10)	(0.05)	(0.03)
Shallow-water groupers	0.08	0.66*	-0.75*	0.00
	(0.07)	(0.10)	(0.06)	(0.04)
Shallow and mid-water snappers	0.05	-0.65*	0.76*	-0.17*
	(0.03)	(0.05)	(0.07)	(0.03)
Miscellaneous species	-0.45*	0.00	-0.45*	0.90*
	(0.06)	(0.09)	(0.09)	(0.10)
Effort	0.01	0.27**	0.15	1.20*
	(0.08)	(0.14)	(0.20)	(0.26)

Significance levels: 0.01,0.05** and 0.1****

Table I.8: Input-compensated own and cross price and scale elasticities for the longline fleet (standard errors in parenthesis).

Prices and effort	Elasticity		
	Red grouper	Shallow-water grouper	Miscellaneous species
Red grouper	0.34***	-0.25	-0.09**
	(0.19)	(0.19)	(0.04)
Shallow-water groupers	-0.54	0.50	0.04
	(0.42)	(0.42)	(0.70)
Miscellaneous species	-0.28**	0.06	0.22**
	(0.11)	(0.09)	(0.10)
Effort	0.70*	0.99*	1.59*
	(0.19)	(0.24)	(0.30)

Significance levels: 0.01,0.05** and 0.1****

Table I.9: Parameter estimates for red grouper annual wholesale demand function (N=15).

Parameter Estimate	Estimate	Std. Error	t Stat	P-value
Constant	1.79	3.23	0.55	0.59
Import Price	1.08	0.94	1.15	0.28
Disposable income	0.02	0.07	0.29	0.78
GOM red grouper landings	-0.05	0.04	-1.08	0.30

Table I.10: Quasi-rent and marginal values under various allocations

Allocation (gutted weight lbs)	Marginal Benefit ($/lb)	Total Benefit ($ million)
0	3.38	0
500,000.00	2.38	1.276
1,000,000.00	2.21	2.421
1,500,000.00	2.07	3.488
2,000,000.00	1.96	4.496
2,500,000.00	1.85	5.449
3,000,000.00	1.73	6.343
3,500,000.00	1.61	7.178
4,000,000.00	1.48	7.950
4,500,000.00	1.32	8.649
5,000,000.00	1.11	9.258
5,500,000.00	0.84	9.749
6,000,000.00	0.48	10.085
6,477,020.00	0	10.206

Appendix 2. A Hedonic Approach to Valuing Sportfishing Harvest

1. Introduction

There is a considerable amount of research on the value of sportfishing harvest (Johnston et al. 2006). The research aims to estimate angler's willingness-to-pay (WTP) by direct elicitation with contingent valuation models or by observing the relative opportunity cost of access to different harvest characteristics with travel cost models. In either case, however, the valuation measure is not derived from actual market prices. Rather, a constructed market price or a proxy "price" is assumed to vary directly with willingness-to-pay. For example, applications of the travel cost model infer access and harvest values based on the proxy of distance and travel time to fishing sites. In this case, however, estimated values are only as accurate as the calculated proxy prices.[1] The problems in measuring accurate "travel prices" are well-known (Randall 1994; Englin and Shonkwiler 1995; Lew and Larson 2005; Landry and McConnell 2007).

This paper reports on an alternative, hedonic, strategy to estimate the value of sportfishing experiences with data on markets for fishing services offered by charter and guide operations. A similar strategy was applied by Hunt et al. (2005b, a) to value the characteristics of remote fishing operations. The approach uses actual market prices, possibly avoiding the aforementioned measurement problems, which could be important if we are interested in cardinal welfare measures. A leading case concerns resource allocation where there is a need for information about the relative marginal value in alternative uses.

[1] For example, the commonly used trip count estimators imply an access value that is the reciprocal of the coefficient on the travel cost parameter (Haab and McConnell 2002). The absolute value of the travel cost parameter, and therefore the calculated access value, will depend on the measurement of travel cost.

The underlying rationale for the hedonic strategy in the context of recreation demand was recently summarized by Landry and McConnell (2007, p. 1): “When services and activities are commercially available onsite, market prices will reflect relative scarcity of environmental amenities, costs associated with production of services and activities, as well as consumers’ willingness to pay for such services.” Our approach can be thought of as a special case of the hedonic onsite model proposed by Landry and McConnell. However, by focusing on the price of only one product, for-hire sportfishing trips, we avoid the endogeneity issues associated with the combination of time and goods that complicate the onsite cost model. Note that the proposed approach is also distinct from the hedonic travel cost model (Brown and Mendelsohn 1984) that has been criticized for attempting to estimate a hedonic surface using non-market “prices” (Bockstael and McConnell 1999). This distinction is discussed further in the development of the model.

The hedonic strategy for the valuation of sportfishing harvest with market data about charter fishing operates under two primary assumptions. First, each fishing site has an *intrinsic* set of harvest characteristics that are correctly perceived by anglers. This intrinsic set of characteristics can be considered an exogenously given input representing variations in biomass, species distributions, and the incidence of regulations. Given the same level of technology and skill, a charter trip operating from a site with higher intrinsic harvest characteristics will yield larger harvest rates. The concept of a mean harvest as a quality shared by charters operating from the same site also embodies Tirole’s (1996) notion of collective reputation as average group quality. As Landon and Smith (1998, p. 369) explain: “In a market with a large number of firms, …, it may be very costly for consumers to acquire information on the past quality of goods produced by all firms. It is typically less costly for consumers to acquire information on collective (or group) quality that can be used as an indicator of the quality of goods produced by individual firms in the group." For example, information about the expected (*i.e.*, average) fishing quality in different areas is generally available in guide books, fishing reports, magazines, and, of course, via the Internet.

The second operational assumption of the hedonic strategy hypothesizes that the intrinsic harvest characteristics are reflected in charter prices at the site level. For example, sites that exhibit higher intrinsic harvest rates will have higher charter fees on average. This does not necessarily suggest that charter firms operating from sites with higher intrinsic harvest characteristics are enjoying market power in the sense of Taylor and Smith (2000). The hedonic approach values harvest attributes by identifying how charter fees vary with harvest characteristics across sites and by observing where trips are offered and where anglers choose to fish. With this information we hope to reveal, for example, that, all else equal, the average angler must be willing to pay at least $25 for a one fish increase in the intrinsic harvest rate if s/he chooses a $500 trip from a site with a four fish intrinsic harvest rate instead of a $475 trip from a site with a three fish intrinsic harvest rate.

Charter prices in our sample from the Gulf of Mexico are measured at the trip level, whereas the harvest attributes are measured at the site level. Due to data limitations, sites are defined as counties in our application and harvest attributes are aggregated to the county-level. This suggests the use of a multilevel approach that explicitly models the random variation in charter fees across counties (Gelman 2007). Such models have been applied in other hedonic studies where the attributes of interest are measured at higher levels of aggregation than prices (Beron, Murdoch and Thayer 1999; Goodman and Thibodeau 2003; Brown and Uyar 2004; Kristofersson and Rickertsen 2004, 2007). In general, our results suggest that the multilevel estimation approach provides more accurate estimates of standard errors and, therefore, more realistic bounds on implicit prices for harvest attributes in the model.

The next section introduces the hedonic theory of product differentiation as applied to the charter boat market. Section three specifies the hedonic model and describes the estimation method. Sections 4 and 5 describe the data and the results for the Gulf of Mexico application. The final section summarizes the paper and highlights the conclusions.

1. Hedonic Model

The purpose of this section is to adapt the hedonic theory of product differentiation and welfare measurement to markets for fishing charter services. We focus on the portions of the theory that enable us to measure the welfare effects of marginal changes in charter trip harvest attributes with limited data. The valuation of discrete changes in harvest characteristics is not attempted because the information necessary to identify the marginal bid (*i.e.*, inverse demand) function is not available for our application. Also, due to data limitations, the analysis focuses on the decisions that occur at the trip-level and the *number* of trips is not modeled.

Charter boats offer sportfishing trips that can differ in a variety of characteristics: duration, capacity, target species, expected harvest, etc. In most cases, a charter trip can be completely described by these characteristics, and anglers purchase the charter trips that satisfy their demand for trip characteristics. An angler will be *WTP* relatively more for a trip that offers a characteristic that is valued highly. To the extent possible, charter boat operators will respond by offering more trips with relatively valuable attributes. Therefore, following Rosen's (1974) model of product differentiation, the mix of charter trips offered and their trip prices reflect the interaction of buyers and sellers with respect to characteristics in the market.

In equilibrium, anglers have made their utility-maximizing choices of charter trips, and the resulting charter prices just clear the market given the existing trip offerings and characteristics and the prices of alternative trip configurations. Any differences in equilibrium trip prices can be explained in terms of differences in trip characteristics. The relationship between prices and characteristics defines a hedonic price function

$$p = h(\mathbf{z};\gamma) \tag{22}$$

where **z** is a vector of *m* trip characteristics and γ is a vector of parameters describing the shape of the hedonic function. At this point one might be tempted to include travel costs in the definition of the price as is done in the hedonic travel cost model (Brown and Mendelsohn 1984). There are two reasons why this is not advisable. First, following the criticisms of the hedonic travel cost model, the inclusion of travel costs would introduce additional noise into the hedonic relationship because there is no reason to expect travel distance and time to sort anglers among counties according to their *WTP* for harvest attributes (Bockstael and McConnell 1999). The market performs this sorting in the context of Rosen's model and provides the behavioral underpinnings of the charter fee hedonic relationship necessary for valid welfare measures.

Second, as the present analysis is primarily interested with measuring marginal values for harvest attributes and not with measuring access value, there is less need to know the "full price" of a fishing trip. Indeed, this complication is avoided when using market prices to derive marginal values because, at any point in time, the observed equilibrium charter fee reflects the decisions of rational anglers and charter operators. For example, all else equal, a fishing charter that is easy to access will be able to charge a higher fee, unless remoteness is a valuable attribute (Hunt et al. 2005a). Consider two charter trips that are identical in every way except in the distance from the angler. If the price of the trip farther away is low enough, then the angler will choose it over the closer, more expensive trip. The equilibrium market prices for charter trips will reflect these trade-offs by all anglers and a similar set of choices by charter firms. In this way, a measure of travel distance is an attribute in the hedonic framework that should already be reflected in the equilibrium charter prices. Adding the opportunity costs of travel to create a "full price" would be double-counting.[2] Note that even if some measure of travel distance such as distance from an airport is an attribute in the charter fee hedonic, its omission would bias the implicit price (*i.e*., marginal value) of harvest attributes only in the unlikely case that distance is correlated with the harvest attributes.

The derivative of the hedonic function with respect to an attribute gives the implicit price of that attribute. It is reasonable to expect that implicit prices will be non-linear with respect to differences in the levels of each attribute because most attributes of charter boat trips cannot be costlessly repackaged in the short run. For example, it is unlikely that two half day trips are equivalent to one full day trip or that a single trip that harvests ten fish is the same as two trips that harvest five fish each. Even if repackaging were costless, arbitrage does not act in the charter market to equalize the total price of two half day trips with that of one full day trip, or two five-fish harvest trips with one ten-fish harvest trip. Ekeland et al. (2004) demonstrate the implausible assumptions implicit in the structural model that implies a linear hedonic equation. Consequently, we would expect that the additional amount paid (*i.e*., the implicit price) for increasingly high amounts of attributes such as harvest rates would decline as the total level of the attribute increases.

The problem for the charter boat firms is to maximize profit per trip, $\Pi = h(\mathbf{z}; \gamma) - c(\mathbf{z}; \varphi)$, where $c(\cdot)$ describes the cost of producing a trip with characteristics $\mathbf{z}$, and φ is a vector

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[2] McConnell (1990) makes a similar point regarding travel cost models of recreation demand and hedonic analyses of housing prices.

characterizing individual producers. Note that there is a set of short-run trip attributes that are provided costlessly to the charter firm once they have set up their operation. These are either structural attributes fixed after the initial purchase, such as boat length and engine size, or exogenous attributes associated with location, marina, or environmental conditions. In the present case, the intrinsic harvest characteristics that are available from the charter boat county of origin are the exogenous attributes of interest.

The notion of intrinsic county-level harvest characteristics merits further discussion. We are interested in the portion of the county-level harvest characteristics that are given exogenously in the production process and serve as an indicator for anglers of quality of the fishing experience. As mentioned in the Introduction, this intrinsic portion can be considered to be an exogenous input representing variations in biomass, species distributions, and the incidence of regulations. Therefore, the county-level intrinsic harvest rate and other harvest characteristics will depend on the relative distribution of biomass and the incidence of regulations. Note that this conception of the intrinsic harvest rate summarizes the biologically determined "catch rate" and the endogenous "landings rate" common in models of angler behavior (Anderson 1993; Woodward and Griffin 2003). Also, as noted in the Introduction, intrinsic harvest characteristics are intended to measure average quality and serve as an indicator of the collective fishing reputation for charters operating out of the same county. We assume that the harvest rate and other harvest characteristics are summarized in measures for *all species combined* because there was not sufficient data in our application to consider individual species separately.

The minimum payment a charter firm requires to maintain a given profit level, Π^0, for a charter trip with a given intrinsic harvest characteristic, z_1, is described by the offer function, $o = o\left(z_1; \mathbf{z}_{-1}, \varphi, \Pi^0\right)$, that holds all other attributes constant at $\mathbf{z}_{-1}$. Since the intrinsic harvest characteristic is given exogenously, the offer price for this attribute depends only on the level of profit attainable. Therefore, the equilibrium price is determined entirely by angler demand once the intrinsic harvest characteristic has been established.

Given the hedonic price function, the angler's problem for any trip is to maximize the preference function, $u(x, \mathbf{z}; \phi)$, subject to a budget constraint, $y = h(\mathbf{z}; \gamma) + x$, where ϕ is a vector of parameters for the preference function and x is a composite commodity with a price normalized to unity. Note that this problem also can be represented as the choice over any one intrinsic harvest characteristic, say z_1, on the trip

(23) $$u\left(z_1, y^0 - b; \mathbf{z}_{-1}, \phi\right) = u^0$$

where b is the bid for charter trips that only vary in z_1, holding utility, income, and all other attributes constant at u^0, y^0, and $\mathbf{z}_{-1}$, respectively. The bid b implicitly measures the angler's *WTP* in terms of the income (or expenditures on other goods) necessary to maintain a constant utility level as the harvest characteristic changes. Inverting expression (23), the bid function is obtained as

(24) $$b = b\left(z_1; \mathbf{z}_{-1}, y^0, \phi, u^0\right)$$

to explicitly show the angler's *WTP* as a function of the harvest characteristic, holding income, utility, and all other characteristics constant. Note that in this formulation, the bid function defines an indifference curve between the harvest characteristic and expenditure on other goods.

The derivative of the bid function with respect to z_1 gives the inverse compensated demand function for this harvest characteristic. This is useful for characterizing the first order conditions for the solution to the angler's problem

(25) $$\frac{\partial u / \partial z_i}{\partial u / \partial x} = \frac{\partial h}{\partial z_i} = \frac{\partial b}{\partial z_i} \qquad i = 1, \ldots, m$$

where the bid function is evaluated at the highest level of utility obtainable. Equation (25) indicates that the optimal choice of harvest rate occurs where the implicit price of a change in the harvest rate equals the angler's marginal *WTP* (*MWTP*) on any given trip. Note that, in general, expression (25) does not suggest that the derivative of the hedonic price function with respect to an attribute is a *MWTP function* for changes in that attribute (McConnell and Phipps 1987). Only at the chosen level of z_1 does the derivative of the hedonic function equal the angler's *MWTP*. At this point, it measures the additional money that the angler with a specific set of income, preferences, and characteristics would pay to purchase a charter trip with a (one unit) higher level of the attribute. Other anglers with a different set of income, preferences, and characteristics would have a different equilibrium point on the hedonic schedule. Bayer et al. (2007) show that the average estimated implicit price will approximate the mean *MWTP* when the attribute varies more or less continuously throughout the market. Note that equilibrium implicit prices will exactly reflect mean preferences only when anglers are homogeneous. With heterogeneous anglers, the equilibrium implicit price for a specific attribute level reflects the *MWTP* of individuals on the margin between locations defining the change in attribute level.

To demonstrate, we adapt the simple example in Bayer et al. (2007) to the charter boat market. Take, for example, charter trips that can reasonably offer the harvest of a specific species. If the species were available in only a few counties, then the hedonic price would reflect the *MWTP* of an angler with a relatively strong taste for the species. In this case, the mean *MWTP* is less than the implicit price because the majority of anglers are not *WTP* the equilibrium hedonic price.

If we now consider a more continuous attribute, such as the harvest rate, then there are several margins. The margins correspond with the differences in each pair of counties ranked according to harvest rate. If there are roughly an equal number of charter trips to each county, then averaging the equilibrium implicit price over all anglers in the sample approximates the mean *MWTP* of all anglers. Therefore, in the present case, the mean *MWTP* for characteristic *i* is approximated by

$$\overline{MWTP_i} \approx N^{-1} \sum_{n=1}^{N} \frac{\partial \hat{h}(\overline{\mathbf{z}}_n)}{\partial z_{i,n}} \approx \sum_{j=1}^{J} \pi_j \frac{\partial \hat{h}(\overline{\mathbf{z}}_j)}{\partial z_{i,j}}. \tag{26}$$

where *N* is the total number of trips and π_j is the proportion of total trips taken to county $j = 1, 2, \ldots, J$. Note that the expression in the second summation arises because harvest characteristics measured at the county level imply that each angler on every trip to the same county will be at the same margin and have the same *MWTP*.

2. Specification and Estimation

Theory does not offer guidance for the specification of the hedonic price function. Rather, the form of the price function is generally determined with an understanding of the market and measures of equation fit. We assume that offshore charter trips in the Gulf of Mexico are all offered in the same market, and we attempt to identify the effects of cross-county variations in intrinsic harvest characteristics on the equilibrium market price. Variations across counties, instead of trips or vessels, are examined for two reasons. First, charter fee and harvest information was not available in our study area for the same set of trips. One dataset had information about fees and another had information about harvests. Second, even if harvest data for each trip were available, this would represent the *ex post* quality of the trip and not the expected quality that clients and captains consider when negotiating a price.

There are many ways to characterize the expected quality of a trip using harvest data (Freeman 1995). As described in the previous section, we hypothesize that the exogenous portion of expected trip quality is indexed by the county-level intrinsic harvest characteristics. We proxy the intrinsic harvest characteristics with ten year averages for weight per fish, number of fish kept per unit effort, and discard per unit effort in each county. In the hedonic approach, the link between the exogenous intrinsic harvest characteristics and equilibrium charter trip prices is of interest. Therefore, we model the intrinsic harvest characteristics directly rather than as arguments of a function for expected harvest quality per trip (McConnell et. al. 1995).

Other key attributes in the hedonic function include the duration of the charter trip and the number of passengers. These factors explain nearly seventy percent of the variation in charter fees. Additional attributes such as boat length and hours fished were omitted due to their high correlation with duration and passengers. Data about more specific features of the charter boat or trip (*e.g.*, air conditioning) were not available in our dataset.

Multilevel specification and estimation are pursued because of the known power issues associated with models that have variables measured at different levels of aggregation. Specifically, ordinary least squares (OLS) standard errors have been shown to be biased downwards when observations are correlated within each group or, in our case, county (Moulton 1990). The hedonic price function for the Gulf of Mexico charter market is specified as variations on the following multilevel model (MLM)

(27) $$p_{i,j} = \alpha_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \varepsilon_{i.j}$$

where p_{ij}, t_{ij}, and g_{ij} are the price, hours fished per trip, and number of passengers, respectively, for charter trip i taken in county j, α_j is a random intercept that measures the variation in fees across counties and $\varepsilon_{ij} \sim iid\ N(0, \sigma_0^2)$.[3]

[3] Other multilevel specifications were considered; most notably, those that allowed the parameter for trip length to vary randomly across counties. However, the data did not support the

Three different specifications are examined for the county level variation

(28)a $$\alpha_j = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \nu_j$$

(28)b $$\alpha_j = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \alpha_4 k_j^2 + \nu_j$$

(28)c $$\alpha_j = \alpha_0 + \alpha_5 \ln w_j + \alpha_6 \ln k_j + \alpha_7 \ln d_j + \nu_j$$

where w_j is the average weight per fish, k_j is the average keep per unit effort, d_j is average discard per unit effort in each county, and $\nu_j \sim iid\ N(0, \sigma_1^2)$. The level two county area error, ν_j, is assumed to be independent of the level one error, ε_{ij}, and the explanatory variables. Note that the measure of effort is angler hours fished per trip. The three specifications can be rewritten by inserting the level two models into the level one equation:

(27)a $$p_{i,j} = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{\nu_j + \varepsilon_{i.j}\right\}$$

(27)b $$p_{i,j} = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \alpha_4 k_j^2 + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{\nu_j + \varepsilon_{i.j}\right\}$$

(27)c $$p_{i,j} = \alpha_0 + \alpha_5 \ln w_j + \alpha_6 \ln k_j + \alpha_7 \ln d_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{\nu_j + \varepsilon_{i.j}\right\}.$$

These forms of the model highlight the separate variance components and the implied heteroskedasticity over county areas. The models are estimated via restricted maximum likelihood using the MIXED procedure in SAS.[4] An additional null model, equivalent to (27)a with $\alpha_1 = \alpha_2 = \alpha_3 = \beta_1 = \beta_2 = 0$, is estimated to formally examine the county-level variation in charter fees and to calculate the raw variance partition coefficient (VPC). The VPC measures the proportion of the total variance in charter fees that occurs among counties as $\rho = \sigma_1^2/(\sigma_0^2 + \sigma_1^2)$.

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estimation of these more complex specifications. Specifications that included simple interactions between the harvest variables and trip length also were unsuccessful at fitting the data.

[4] See the Appendix in Kristofersson and Rickertsen (2007) for an outline of the MIXED procedure in SAS as applied to the estimation of hedonic price equations. Singer (1998) also provides a detailed discussion on using the MIXED procedure to estimate of multilevel models.

This measure is equivalent to the so-called intra-class correlation coefficient in the linear model without interactions and measures within county dependency.

The average equilibrium implicit price and *MWTP* approximations for a change in key harvest attributes with the three specifications are given in Table II.1 where A_j denotes the average angler hours fished per trip in county j. These formulae correspond with expression (26). Note that measurements of fish weights in kilograms are scaled to pounds in the formulae by dividing by 2.2.

3. Data

The data for the estimation of the hedonic model of harvest value in the charter boat market comes from three sources, all of which are affiliated with the Marine Recreational Fisheries Statistics Survey (MRFSS).[5] In all cases we selected sub-samples to correspond with single-day charter trips, fishing offshore.

Information about charter fees was obtained from an add-on to the weekly MRFSS For-Hire telephone survey conducted from 07/01/02 to 06/30/03. In this add-on, charter captains were randomly selected from a master registry of 700 vessels to answer questions about trips taken in the week prior to the call. Captains were asked about the number and general characteristics of the trips they took in the prior week and were asked to report cost and price information for one of the trips. There was no information collected about the catch on any of these trips.[6]

[5] More information about the MRFSS is available on the world wide web at: www.st.nmfs.noaa.gov/st1/recreational/overview/overview.html.

[6] There may have been catch information collected in the MRFSS intercept survey for the same trips reported by the captains in the for-hire telephone survey. However, there is no clear way to identify and link these records.

We began with a sub-sample of single day, offshore trips that either bottom fished or fished via trolling, casting, or drifting. One large vessel (>80ft.) with 10 trips, 3 of which had cost and price information, and one vessel with one low fee trip ($50) were removed. The final sample consisted of 356 vessels taking a total of 1,935 fishing trips, 584 of which had corresponding cost and price information. Note that trips were not reported from every county along the Gulf of Mexico and that we have assigned observations in counties with fewer than three reported trips to adjacent counties. This reduced the number of county areas from 28 to 23. Table II.2 shows the average charter fee excluding tips (p), number of passengers (g), and boat hours (t) per trip for each sampled county area in the Gulf of Mexico. Note that the identity of the counties has been obscured to protect the privacy of operators in counties with a small number of charter operators. The number of sample observations in each county is shown in the table.

Estimates of the average keep per unit effort (k), discards per unit effort (d), and weight per fish (w) across all species are calculated from the MRFSS intercept survey data for each county area in the Gulf of Mexico. The average is over all species because we are unable to separately identify the effects of individual species or groupings on charter fees with a reasonable degree of statistical confidence. The effect of the red snapper harvest rate could be identified, but it was highly correlated with the overall harvest rate because red snapper is such a popular species.[7]

To be consistent with the MRFSS economic add-on sample, only single day charter trips fishing offshore with hook and line are included in the sample. There were 13,025 such trips sampled in the ten years (1992-2001) prior to the MRFSS economic add-on survey. The data for

[7] Correlation matrices are available upon request for keep and discard rates for the top recreational species in the Gulf of Mexico.

the 109,989 fish measured on these trips were used to calculate the average weight per fish. The *k* and *d* across all species are calculated for each charter trip intercepted as the total observed harvest in numbers of fish (MRFSS Type A) and reported live discards in numbers of fish (MRFSS Type B2), respectively, divided by angler hours (*A*) given as the product of the hours fished on the trip and the number of fishing party members.[8] The variables *k*, *d*, and *A* are averaged over all trips and *w* is averaged over all fish for each county area in the Gulf of Mexico from 1992-2001 as shown in Table II.3.

An estimate of the population proportion of the offshore charter trips originating in each county was generated as an annual average of trips observed in the MRFSS intercept survey. The estimated county shares from 2000 to 2006 are shown in Table II.4 along with the annual average for each county (π_j) over the period that was used in the calculation of the mean *MWTP* in Table II.1. The MRFSS intercept averages for *k*, *d*, and *w* were merged with the economic add-on survey by county area. The summary statistics for all model variables over the final combined sample are shown in Table II.5.

4. Results

The parameter estimates for the seven estimated models are shown in Table II.6. Measures of model fit are also presented, including negative two times the log-likelihood (-2 *LL*), the adjusted Akaike Information Criterion (*AICC*), and the coefficient of determination (R^2). Note that the R^2 for the OLS models is adjusted for the number of variables in the model and the R^2 for the multilevel models is measured as the proportional reduction in errors of prediction when the model is compared with the null model (Kreft and de Leeuw 1998). Standard tests

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[8] Reported dead discards (MRFSS Type B1) are typically a very small proportion of the total catch and are, therefore, not considered in this analysis.

reject the normality of the level one (trip) residuals, but fail to reject the normality of the level two (county) residuals for all of the MLM specifications except the null model.[9] Closer examination of the level one residuals suggests that the departure from normality is due to excess kurtosis. However, this is not an issue because the primary interest is in the estimation of parameters for the county-level harvest variables.

OLS estimates of the parameters for the three specifications are shown in the first three columns of Table II.6. Based on the adjusted R^2 measure, these models have a similar fit with the exogenous variables explaining nearly seventy percent of the variation in charter fees. The estimates of means and standard errors for the parameters on *g* and *t* are also similar across the OLS models as are the estimates of the model variance, σ_0^2. The primary difference among the specifications occurs among estimates for the county level harvest characteristics.

The MLM estimates for the three model specifications are shown in the last three columns of Table II.6, and the fourth column shows the results for the estimation of the null MLM. Recall that the VPC estimated from the null model indicates the proportion of variation in charter fees that occurs across counties. In this case, more than 30 percent of the explainable variation in charter fees occurs across counties. Figure II.1 shows the mean and confidence interval (at the 0.05 level) of charter fees estimated for each county based on the random intercepts. This is the variation that we hope to explain with variations in harvest characteristics across counties.

The relatively high degree of clustering of charter fees within counties suggests that OLS will underestimate the standard errors on the county-level harvest characteristics. Indeed, the standard errors of the county-level harvest parameter estimates in the first three columns are

[9] Results for the Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling and Chi-square normality tests are available upon request.

smaller than the corresponding estimates in columns five through six. This indicates that, if the assumptions of the MLM are correct, the OLS estimates will suggest confidence intervals that are too narrow and will be more likely to reject tests about parameter values.[10] For example, the OLS estimates incorrectly reject the hypothesis that the parameters on the weight variables (α_1 and α_5) are equal to zero at the 0.05 level.

The mean implicit prices and mean *MWTP* of the variables that enter the model linearly are simply the corresponding coefficient estimates. For example, looking at the MLM results for the logarithmic model, charter firms charge \$75.92(±\$7.3) on average for each additional trip hour and \$53.57(±\$6.9) extra on average for an additional passenger.[11] Note that, as described above, OLS underestimates the standard errors of the county (level two) harvest variables. Consequently, the OLS bounds are too narrow relative to the more accurate bounds estimated with the MLM models. For example, the confidence interval for MLM estimates of the parameter on weight, *w*, contains zero and negative values, whereas the bounds on the OLS estimates are everywhere positive.

The marginal values of the harvest characteristics are the primary interest of this study. Table II.7 shows the calculation of the mean *MWTP* approximations from Table II.1 using the MLM estimates over the three specifications. The upper and lower bounds of the estimates are shown based on a 95 percent confidence interval.

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[10] Additionally, the degrees of freedom in the MLM significance tests for the harvest characteristics are more conservatively based on the number of county areas, rather than the total number of observations.

[11] The numbers in parenthesis are confidence intervals based on a 0.05 significance level. The validity of these and other calculated bounds on the model parameters depend on the validity of the normality assumption. We have already noted that the hypothesis of normality was rejected for the (trip) level one residuals. More robust nonparametric confidence intervals can be calculated using bootstrap (Wang, Carpenter and Kepler 2006) or MCMC methods (Maindonald 2007).

Results presented in Table II.7 indicate that the means and bounds of the estimates vary somewhat depending on the specification. In particular, there is a noticeable difference between the calculations based on a single parameter estimate and those that are multiplied by a weighted factor. This occurs because the data were not weighted in the regressions.[12] The formulae in Table II.1 suggest that the estimates in the first three rows of Table II.7 are most likely to demonstrate this difference. For example, the mean *MWTP* to catch and keep an extra fish during each angler hour fished when calculated with the linear specification ($64.72) is considerably lower than the estimate with the logarithmic ($115.43) and quadratic ($120.72) models. A similar discrepancy occurs among the estimates of the mean *MWTP* to discard one less fish per angler hour. However, in this case, the linear (-$25.52) and quadratic (-$19.69) estimates are similar and both are different than the estimate from the logarithmic (-$59.60) model. Again, referring to Table II.1, the linear and quadratic calculations are based on the parameter estimate alone, whereas the logarithmic calculation involves a weighted factor. These discrepancies carry over to the other calculations in the table that are constructed using similar parameter combinations. In all cases, however, the calculations involving the weighted factors provide wider bounds on the estimates than those based solely on one parameter. Furthermore, the estimates with weighted factors include the county proportions that are consistent with the distribution of trips across counties in the population. This suggests that the calculations involving the weighted factors are likely to be more accurate measures of population mean *MWTP* because they incorporate additional heterogeneity across counties. In the interest of

[12] The parameter estimates of the regressions will be unbiased without weighting as long as the weights are uncorrelated with the independent variables. Results based on the Hausman-type test presented in DuMouchel and Duncan (1983) suggests that this is a valid assumption with respect to the harvest variables.

brevity, the following discussion concentrates on the estimated mean *MWTP* from the logarithmic specification.

Focusing on the estimates for the logarithmic MLM, anglers are *WTP* $26.89 on average to increase the expected (average) weight per fish kept on a trip by one pound. However, the confidence bounds on this estimate are quite wide, suggesting a marginal value of anywhere between -$4.40 and $58.19. The bounds on the keep rate are tighter, but still cover a wide range of values. On average, an angler is *WTP* $115.43 more per trip to increase by one the expected (average) number of fish kept for each hour fished per angler. This translates to a *WTP* of $5.86 for an additional fish kept per trip. The estimate is on the lower end of the *WTP* per fish reported from the sample of studies analyzed by Johnston et al. (2006).[13]

The results for the discard rates from the MLM-logarithmic model suggest that, on average, anglers would be *WTP* $2.90 to avoid throwing back an additional fish per trip. Interestingly, the marginal value of keep and discards is not symmetrical with anglers *WTP* more to keep a fish than they are *WTP* to avoid throwing one back. Again, though, the 95 percent confidence interval for the marginal value of the discard rate is wide, including both positive and negative values.

As shown in Table II.1 and reported in Table II.7, the mean *MWTP* per pound of fish kept per trip is calculated two ways. The first approach assumes that the one pound increase is achieved via one more fish kept at the average weight. Using the MLM estimates for the logarithmic model, this approach gives a mean *MWTP* per pound of $1.11. The second way assumes that the one pound increase is achieved via heavier fish, effectively increasing the weight of each fish kept per trip. Using the MLM estimates of the logarithmic model, this

[13] The Johnston et al. estimates are also denominated in (June) 2003 dollars.

approach gives a mean *MWTP* per pound of \$1.56. The ninety-five percent confidence interval calculated with the second method contains the interval calculated with the first approach. Note from Table II.1, the two calculations in the logarithmic specification involve two different parameters (α_6 and α_5), but the same scaling factor. Therefore, a test of the difference in these parameters is a test of whether the two approaches of calculating the mean *MWTP* per pound per trip produce statistically different results. A t-test (df=19) of the hypothesis that $\alpha_6 - \alpha_5 = 0$ cannot be rejected with any reasonable degree of confidence (p= 0.6683) suggesting that, in effect, "a pound is a pound," regardless of how it is obtained.

5. Summary and Conclusions

This paper introduced a novel approach to valuing recreational fishing harvest using data from markets for sportfishing services. The approach uses the hedonic theory of product differentiation to model the variation in charter trip fees associated with variations in trip and harvest attributes across locations. Expressions for calculating the mean *MWTP* of harvest attributes were derived directly from variations in reported fees in the charter market.

The hedonic approach was applied to estimate the marginal value of fish kept, fish discarded, and the average weight per fish in the market for offshore charter fishing in the Gulf of Mexico. Three alternative specifications of the hedonic function were estimated using both OLS and multilevel modeling techniques. The MLM estimators were examined because the harvest attributes were measured at a higher level of aggregation (county) than the prices and trip attributes.

Preliminary testing found that charter fees were clustered within counties in the Gulf of Mexico and that a significant portion of the explainable variation in fees occurred across counties. This fact led to OLS standard errors for the county-level harvest characteristics that were smaller than those estimated via MLM techniques. This finding was consistent across hedonic specifications.

The average *MWTP* was calculated for changes in the average weight per fish kept and the number of fish kept and discarded per angler hour fished and per trip. The estimates were within the range of values estimated in other research. Point estimates suggested that the anglers are *WTP* more to keep an extra fish than they are to avoid throwing one back. We also found that, for the logistic model specification, the *MWTP* for an additional pound of fish is not statically different whether achieved via more fish or via heavier fish.

In using actual market prices, the hedonic approach can provide cardinal measures of *MWTP* that are free of the measurement problems that trouble methods such as travel cost models that use proxy prices. Cardinal measures of *MWTP* may be important, for example, when evaluating the efficiency of resource allocations among competing uses. It is important to note, however, the key assumptions that underlie the valuation estimates derived from the hedonic model. Specifically, we are assuming that the market for charter services is in a perfectly competitive equilibrium and that variations in (county-level) intrinsic harvest characteristics are reflected in the distribution of charter fees. For this to happen, the spatial distribution of the harvest characteristics needs to be understood by both firms and anglers and spatial arbitrage cannot act to equalize prices across the market. This is likely because ecosystem services, such as intrinsic harvest characteristics, are not spatially fungible; therefore, the benefits of these services are spatially explicit (Boyd and Banzhaf 2007). We also hypothesized that the variations in the intrinsic harvest characteristics are exogenous to the firm's supply of charter services and reflect the distribution of species, biomass, and the incidence of regulations.

Assumptions were also made in the empirical application of the hedonic model. However, most of these assumptions, such those relating to the functional form and error distributions, are typical in applied valuation research. Of particular importance, though, is the assumption that the intrinsic harvest characteristics are uncorrelated with any of the unobservable components that determine charter fees. Also note the mean *MWTP* was assumed to be approximated by the weighted average implicit prices for each harvest attribute and that mean anglers per trip, hours fished per trip, and weight per fish were fixed in these calculations.

In closing note that, as with all hedonic valuation methods, information about preferences beyond *MWTP* is not forthcoming without further assumptions or data (Palmquist 2005). Such information is necessary to evaluate the welfare effects of discrete changes in harvest characteristics. The application of methods designed to identify or bound the value of discrete changes to the hedonic charter model is left for future research.

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Table II.1. Mean *MWTP* Approximations

Measure	Specification		
	Linear	Logarithmic	Quadratic
Mean *MWTP* per keep per angler hour fished (*$/fish/hour*)	α_2	$\alpha_6 \sum_{j=1}^{J} \frac{\pi_j}{k_j}$	$\alpha_2 + \alpha_4 \sum_{j=1}^{J} \pi_j k_j$
Mean *MWTP* per discard per angler hour fished (*$/fish/hour*)	α_3	$\alpha_7 \sum_{j=1}^{J} \frac{\pi_j}{d_j}$	α_3
Mean *MWTP* for an extra pound per fish kept (*$/lb/fish*)	$\alpha_1/2.2$	$\frac{\alpha_5}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{w_j}$	$\alpha_1/2.2$
Mean *MWTP* per keep per trip (*$/fish/trip*)	$\alpha_2 \sum_{j=1}^{J} \frac{\pi_j}{A_j}$	$\alpha_6 \sum_{j=1}^{J} \frac{\pi_j}{k_j A_j}$	$\alpha_2 \sum_{j=1}^{J} \frac{\pi_j}{A_j}$ $+ .5\alpha_4 \sum_{j=1}^{J} \frac{\pi_j k_j}{A_j}$
Mean *MWTP* per discard per trip (*$/fish/trip*)	$\alpha_3 \sum_{j=1}^{J} \frac{\pi_j}{A_j}$	$\alpha_7 \sum_{j=1}^{J} \frac{\pi_j}{d_j A_j}$	$\alpha_3 \sum_{j=1}^{J} \frac{\pi_j}{A_j}$
Mean *MWTP* per pound per trip (achieved via one more keep) (*$/lb/trip*)	$\frac{\alpha_2}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{A_j w_j}$	$\frac{\alpha_6}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{k_j A_j w_j}$	$\frac{\alpha_2}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{A_j w_j}$ $+ \frac{.5\alpha_4}{2.2} \sum_{j=1}^{J} \frac{\pi_j k_j}{A_j w_j}$
Mean *MWTP* per pound per trip (achieved via heavier fish) (*$/lb/trip*)	$\frac{\alpha_1}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{k_j A_j}$	$\frac{\alpha_5}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{k_j A_j w_j}$	$\frac{\alpha_1}{2.2} \sum_{j=1}^{J} \frac{\pi_j}{k_j A_j}$

Notes: The variables k_j, d_j, and A_j measure, respectively, the mean keep per angler hour fished, mean discards per angler hour fished, and mean angler hours fished per trip from each county j. w is the average weight per fish in kilograms and π_j is the annual proportion of total trips from each county j.

Table II.2. 2002-03 For-Hire Economic Survey, County Averages for 584 charter trips

County	Obs.	*p*	*g*	*t*
C1	123	819.28	5.91	7.28
C2	14	907.14	5.57	9.57
C3	48	808.23	5.83	8.39
C4	3	491.67	5.00	8.17
C5	6	370.83	2.67	7.50
C6	18	465.00	4.11	6.25
C7	37	707.86	7.03	7.77
C8	12	636.67	4.00	8.13
C9	6	425.00	3.50	6.33
C10	4	468.75	3.75	7.50
C11	11	557.73	5.00	7.05
C12	68	531.69	3.31	6.56
C13	104	771.00	6.38	7.50
C14	3	333.33	3.00	6.50
C15	38	545.34	4.42	6.91
C16	24	414.29	3.75	5.63
C17	6	466.67	4.00	8.67
C18	7	735.71	5.57	9.93
C19	6	925.00	4.83	10.17
C20	9	1372.22	10.33	9.50
C21	14	1007.14	4.36	10.57
C22	17	619.71	4.06	8.12
C23	6	984.17	10.17	8.92

Notes: The sample size, Obs., in the per trip averages indicates the number of trips sampled. Variable *p* measures average charter fee per trip, *g* measures average number of passengers per trip, and *t* measures average boat hours per trip.

Table II.3. Averages for charter trips intercepted by the MRFSS from 1992 to 2001

	per Trip				per Fish	
County	Obs.	*k*	*d*	*A*	Obs.	*w*
C1	1453	2.03	1.04	22.43	24409	1.53
C2	36	3.82	1.51	33.85	700	1.52
C3	722	1.35	0.39	24.10	8354	1.47
C4	11	1.23	1.72	24.00	125	0.95
C5	79	0.39	0.83	17.44	263	1.52
C6	167	0.71	2.26	15.47	753	1.48
C7	103	1.71	0.89	36.24	1614	1.59
C8	36	0.88	1.48	18.69	195	1.48
C9	48	0.92	1.76	20.82	92	1.34
C10	72	0.99	2.24	18.45	304	1.23
C11	46	0.71	0.79	22.23	452	1.40
C12	5388	0.55	0.37	18.56	20671	3.19
C13	2316	1.29	0.72	26.46	33638	1.96
C14	73	0.20	0.81	13.97	123	1.40
C15	829	1.01	1.09	18.31	7470	1.89
C16	148	0.74	2.01	17.17	1048	1.97
C17	54	0.89	1.36	21.92	477	1.06
C18	28	1.66	1.32	25.68	330	2.70
C19	60	1.33	0.53	25.13	328	2.45
C20	81	2.06	1.27	45.89	744	1.94
C21	256	1.32	0.58	23.79	1621	3.03
C22	204	2.16	1.01	23.75	1530	2.04
C23	815	0.93	0.49	32.11	4748	2.41

Notes: The variables *k*, *d*, and *A* measure, respectively, the mean keep per angler hour fished, mean discards per angler hour fished, and mean angler hours fished per trip. *w* measures the average weight per fish in kilograms. The sample size, Obs., in the per trip averages indicates the number of trips sampled, whereas the sample size, Obs., for per fish average weight indicates the number of fish sampled.

Table II.4. 2000-2006 Annual County Shares of Offshore Charter Trips (percentage by county)

County	2000	2001	2002	2003	2004	2005	2006	π_j
C1	9.1	9.46	8.58	6.2	5.98	5.53	6.95	7.40
C2	0.1	0.21	0.16	0.39	0.35	0.2	0.38	0.26
C3	10.27	5.58	7.43	7.5	9.25	10.51	8.67	8.46
C4	0.07	0	0	0.08	0.04	0.1	0	0.04
C5	0.27	0.38	0.86	1.1	3.19	1.52	1.59	1.27
C6	0.9	0.54	0.86	2.35	2.28	3.03	0.83	1.54
C7	0.7	0.92	1.06	1.33	1.38	1.52	2.49	1.34
C8	0.27	0.08	0.08	1.02	0.79	0.88	1.34	0.64
C9	0.37	0.21	0.78	1.33	1.38	3.08	1.27	1.20
C10	0.47	0.38	0.41	0.35	0.63	0.2	0.25	0.38
C11	0.9	0.25	0.41	1.33	1.54	0.44	0.45	0.76
C12	42.37	47.46	45.06	43.01	30.4	35.94	33.21	39.63
C13	21.47	19.46	16.79	16.01	25.1	23.62	27.09	21.36
C14	0.37	0.54	0.49	0.98	0.47	0.64	0.7	0.60
C15	4.41	7.25	7.52	8.16	8.78	5.87	4.72	6.67
C16	0.7	0.58	2.04	2.79	1.81	1.76	0.25	1.42
C17	0.47	0.13	0.16	0.27	0.43	0.44	0.13	0.29
C18	0.47	0.38	0.33	1.1	1.1	0.88	0.89	0.74
C19	0.54	0.29	0.57	0.27	0.47	0.34	0.38	0.41
C20	0.03	0.04	0.16	0.35	0.63	0.39	5.35	0.99
C21	1.34	1.92	2.37	1.22	1.18	1.61	0.83	1.50
C22	0.3	0.42	1.55	1.18	1.3	0.49	0.96	0.89
C23	4.11	3.54	2.33	1.65	1.5	1.03	1.27	2.20
Total	100	100	100	100	100	100	100	100

Source: MRFSS intercept survey. π_j averages the annual proportions in each county observed between 2000 and 2006.

Table II.5. Sample Summary Statistics for 584 charter trips

Variable	Mean	Std Dev	Minimum	Maximum
p	707.40	360.29	200.00	2300.00
g	5.34	2.77	1.00	20.00
t	7.52	2.52	2.00	15.50
w	1.91	0.57	0.95	3.19
k	1.39	0.65	0.20	3.82
d	0.94	0.47	0.37	2.26
ln(k)	0.21	0.50	-1.63	1.34
ln(d)	-0.18	0.50	-0.99	0.82
ln(w)	0.61	0.27	-0.05	1.16
A	23.67	5.76	13.97	45.89

Table II.6. Parameter Estimates

	OLS			MLM			
Parameter	Linear	Logarithmic	Quadratic	Null	Linear	Logarithmic	Quadratic
α_0	-296.78**	-228.39**	-423.22**	676.68**	-368.57**	-273.44**	-427.46**
	(66)	(38.15)	(84.58)	(50.93)	(114.04)	(54.46)	(131.88)
β_1 (t)	73.52**	73.64**	73.86**		75.9**	75.92**	75.9**
	(3.69)	(3.67)	(3.68)		(3.71)	(3.7)	(3.71)
β_2 (g)	55.64**	54.06**	54.1**		53.93**	53.57**	53.6**
	(3.46)	(3.46)	(3.5)		(3.55)	(3.55)	(3.57)
α_1 (w)	41.02**		59.3**		65.36		65.43
	(19.13)		(20.55)		(38.95)		(39.04)
α_2 (k)	78.56**		187.93**		64.72**		140.3
	(15.24)		(48.47)		(26.74)		(88.8)
α_3 (d)	-35.7*		-20.11		-25.52		-19.69
	(20.89)		(21.82)		(40.84)		(41.45)
α_4 (k^2)			-27.70				-20.50
			11.96				21.86
α_5 (ln$w$)		101.71**				127.27	
		(41.25)				(75.57)	
α_6 (ln$k$)		116.27**				90.54**	
		(20.66)				(34.73)	
α_7 (ln$d$)		-34.19*				-31.32	
		(20.34)				(41.57)	
σ_0^2	43293**	43060**	42948**	103049**	39714**	39715**	39723**
	(2547)	(2533)	(2529)	(6160)	(2375)	(2374)	(2376)
σ_1^2				49435**	5690**	5019**	5727**
				(18546)	(2982)	(2704)	(3109)
ρ				0.32	0.13	0.11	0.13
-2 LL	7849	7844	7836	8436	7820	7817	7811
AICC	7851	7846	7838	8440	7824	7821	7815
R^2	0.6665	0.6683	0.6691		0.7022	0.7066	0.7019

Notes: Standard errors are shown in parentheses below the estimates. *Significant at the 0.10 level. **Significant at the 0.05 level. The R^2 is the adjusted measure for the OLS models and the proportional reduction in errors of prediction compared with the null model for the multilevel models (see text).

Table II.7. Mean *MWTP* Approximations with MLM Estimates ($2002/03)

Measure	Specification		
	Linear	Logarithmic	Quadratic
Mean *MWTP* per keep per angler hour fished (*$/fish/hour*)	117.12	202.20	254.40
	64.72	**115.43**	**120.72**
	12.32	28.65	-12.96
Mean *MWTP* per discard per angler hour fished (*$/fish/hour*)	54.53	95.44	61.55
	-25.52	**-59.60**	**-19.69**
	-105.56	-214.63	-100.94
Mean *MWTP* for an extra pound per fish kept (*$/lb/fish*)	64.28	58.19	64.39
	29.65	**26.89**	**29.68**
	-4.98	-4.40	-5.03
Mean *MWTP* per keep per trip (*$/fish/trip*)	5.59	10.27	13.64
	3.09	**5.86**	**6.25**
	0.59	1.45	-1.14
Mean *MWTP* per discard per trip (*$/fish/trip*)	2.60	4.65	2.94
	-1.22	**-2.90**	**-0.94**
	-5.03	-10.45	-4.81
Mean *MWTP* per pound per trip (achieved via one more keep) (*$/lb/trip*)	1.15	1.95	2.79
	0.64	**1.11**	**1.28**
	0.12	0.28	-0.22
Mean *MWTP* per pound per trip (achieved via heavier fish) (*$/lb/trip*)	4.16	3.39	4.17
	1.92	**1.56**	**1.92**
	-0.32	-0.26	-0.33

Notes: The bold numbers indicate average effects and the numbers above and below indicate upper and lower bounds, respectively, based on a 95 percent confidence interval around mean estimate. The quadratic specification estimates involving *k* are combinations of two estimated parameters as shown in Table II.1Table . Standard errors and the corresponding bounds for these estimates were generated considering the variation in both parameters.

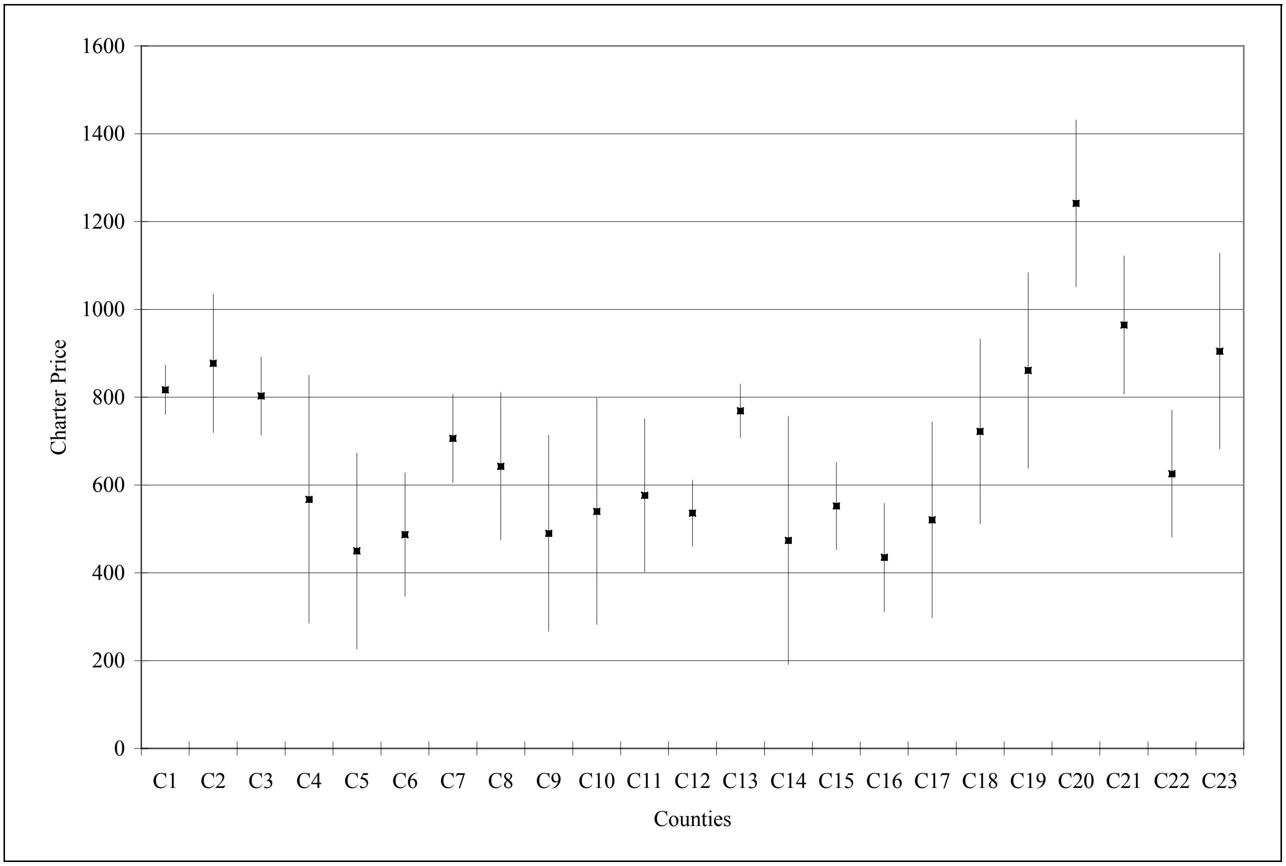

Figure II.1. Estimated Variation in Mean Charter Fee per County

Appendix 3. Adaption of the Recreational Value per Pound for All Species to Red Grouper

Appendix 2 reported an average marginal willingness-to-pay (*MWTP)* of \$1.11(±\$0.64) per pound (achieved via an extra fish) for the recreational sector.[1] Note that this measure was assumed to be the same for all species, including red grouper, and is a function of the county-weighted averages for keep per angler hour fished, angler hours fished, and average weight per fish. One way to tailor the estimate for mean *MWTP* per pound to red grouper is to recalculate the average with "red-grouper" trips only. Given the existing data, this amounts to identifying trips in each county that kept or discarded red grouper and then averaging the *MWTP* per pound over these trips.

Table III.1 shows the annual proportion of trips in each county that either kept or discarded red grouper between 2000 and 2006. The average annual proportion over the seven years is shown in the last column. This average annual proportion can be used to re-scale the proportion of all trips originating from each county as follows

$$\pi_j^{RG} = \frac{\pi_j \kappa_j}{\sum_{j=1}^{J} \pi_j \kappa_j}$$

where κ_j is the average annual proportion of red grouper trips from county *j* and π_j is the average annual proportion of all trips originating from county *j* as defined in Appendix 2. The proportion, π_j^{RG} can be used in place of π_j in the formulas in Table 1 of Appendix 2 to calculate the mean *MWTP* values over red grouper trips.

[1] The values in parentheses indicate the 95 percent confidence interval around the point estimate of the mean *MWTP*. All dollar values in this Appendix are denominated in 2003 dollars unless indicated otherwise.

Calculating the mean *MWTP* for an extra pound per fish in this way gives a value of \$1.03(±\$0.77) per pound if the increase is achieved via an extra fish.[2] This value is lower than the estimate over all fish because the angler hours fished and the keep per angler hour fished on these trips was higher, on average, for red grouper trips than for all trips.[3] In effect, the average keep per trip is higher on trips that kept or discarded red grouper suggesting that these trips are at a higher margin than other trips. The higher margin corresponds with a lower mean *MWTP*. Note that the lower marginal value actually corresponds to a higher total value of harvest per trip. This approach only averages the *MWTP* estimates over the trips that kept or discarded red grouper and, therefore, does not consider the values of other trips that did not catch red grouper. Furthermore, the difference between the mean *MWTP* per pound for all fish and red grouper derives from the difference in the overall keep per trip and the average weight per fish; not necessarily because of differences in species preferences. There was not enough information to identify anglers' species preferences using the model and data reported in Appendix 2.

The measure of mean *MWTP* per pound of red grouper calculated for the recreational sector will be close to the marginal value at the aggregate harvest in 2003 because this was the study year for the analysis. Note, however, that this value is per pound of whole fish and the allocation calculations are typically made in terms of gutted weight. The comparable mean *MWTP* per pound of gutted weight can be found by dividing the whole fish estimate by the poundage gutted weight from a pound of whole fish. According to the SEDAR 12 for

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[2] The mean *MWTP* per pound achieved via heavier fish on red grouper trips is \$1.45(±\$1.68). However, an empirical test reported in Appendix 2 indicated that the mean *MWTP* per pound achieved via an extra fish was not statistically different than the mean *MWTP* per pound achieved via heavier fish.

[3] The average weight per fish on trips that kept or discarded red grouper was slightly lower than the average over all trips.

Gulf of Mexico Red Grouper, there is 0.847 (1/1.18) pounds of gutted weight, on average, in every pound of red grouper harvested. Using this factor, the mean *MWTP* per pound of gutted weight in the recreational sector is $1.21(±$0.91).

Table III.1. Proportion of Offshore Charter Trips Catching Red Grouper in the Gulf of Mexico by County

	2000	2001	2002	2003	2004	2005	2006	2000-2006 (κ_j)
C1	0.00	1.00	12.00	41.00	30.00	27.00	17.00	18.29
C2	0.00	0.00	0.00	30.00	44.00	25.00	0.00	14.14
C3	14.00	25.00	40.00	53.00	54.00	70.00	54.00	44.29
C4	50.00	0.00	0.00	0.00	100.00	100.00	0.00	35.71
C5	0.00	0.00	5.00	4.00	4.00	0.00	4.00	2.43
C6	37.00	62.00	33.00	47.00	55.00	42.00	31.00	43.86
C7	5.00	0.00	12.00	68.00	14.00	61.00	28.00	26.86
C8	38.00	50.00	100.00	85.00	90.00	56.00	76.00	70.71
C9	55.00	0.00	11.00	59.00	63.00	59.00	50.00	42.43
C10	29.00	11.00	50.00	0.00	44.00	25.00	50.00	29.86
C11	37.00	17.00	20.00	62.00	67.00	67.00	57.00	46.71
C12	2.00	4.00	5.00	7.00	6.00	4.00	4.00	4.57
C13	5.00	10.00	22.00	35.00	57.00	52.00	26.00	29.57
C14	9.00	15.00	8.00	12.00	50.00	31.00	0.00	17.86
C15	50.00	51.00	47.00	49.00	54.00	46.00	22.00	45.57
C16	52.00	43.00	38.00	37.00	50.00	56.00	0.00	39.43
C17	43.00	0.00	50.00	14.00	18.00	11.00	0.00	19.43
C18	64.00	100.00	75.00	61.00	43.00	50.00	86.00	68.43
C19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C23	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.29

Source: MRFSS Intercept Survey (Trips where Types A or B2 included red grouper)