TRANSFERABLE RIGHTS IN A RECREATIONAL FISHERY: AN APPLICATION TO THE RED SNAPPER FISHERY IN THE GULF OF MEXICO

A Dissertation

by

HWA NYEON KIM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2007

Major Subject: Agricultural Economics

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Approved by:

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ABSTRACT

Transferable Rights in a Recreational Fishery:

An Application to the Red Snapper Fishery in the Gulf of Mexico. (May 2007)

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Overfishing of red snapper in the Gulf of Mexico has significantly increased lately. A major regulation to reduce the overfishing is Total Allowable Catches (TAC) in combination with a season closure. The restrictions on entry lead to an inefficient outcome, however, because the resource is not used by the fishermen who value it the most. As an alternative to restricting entry, transferable rights (TR) programs are being increasingly considered. Under a TR program, a market is created to trade a right to use a resource and the total benefits of the participants are maximized through such a trade.

The principal objective of this dissertation is to comprehensively assess economic and biological consequences of the red snapper fishery for the TR program. To date the literature lacks sufficient discussion of how recreational TR programs would function. I, therefore, propose an economically desirable institutional framework for the TR program in the recreational fishery. I draw some lessons from hunting programs and applications of other TR programs to find better schemes for the TR program in the recreational fishery.

This dissertation uses theoretical and empirical models as well as institutional settings to develop the TR program. A theoretical model is provided to investigate which unit of measurement for the TRs is preferable. For empirical models I first estimate an empirically based recreation demand that incorporates TR permit demand and then develop a simulation submodel using the estimated demand. I find price instruments, such as fees or TR programs, are very efficient to reduce fishing trips but they also lead to distributional impacts on trips by low income (or low cost) anglers. Partial simulation results indicate that an efficiency benefit of the TR program would be significant because recreational trip demand in the current closed season is not trivial.

I conclude that the TR program in the recreational fishery will economically and biologically provide a great deal of merit to reduce the overfishing situation and a substantial efficiency gain to Gulf anglers. Some institutional barriers, especially from the large transaction cost can also be overcome if electronic systems or the Internet are used.

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CHAPTER I

INTRODUCTION

Congestion and overfishing are serious issues in marine fisheries across the globe, and while commercial fishing is often blamed, there is increasing recognition that recreational fisheries are contributing to these problems. Recreational fishing may also play a role in a solution to these problems (Coleman et al. 2004). For example, the red snapper fishery in the Gulf of Mexico has been overfished due to excess fishing effort by both commercial and recreational sectors. Red snapper stocks have declined since the early 1970s (Goodyear and Phares 1990) and the spawning potential ratio for red snapper is estimated at about 1%, far below the critically overfished level of 20% (MRAG Americas 1997). The decline in the red snapper populations has had direct economic consequences in the commercial and recreational fishery.

The overfishing situation in the recreational sector has become more apparent. Recreational effort targeted toward red snapper stocks has increased substantially in recent years. In only a few years the number of charter vessels increased by 149% and charter angler trips increased by 188% (GMFMC 1999a). As a result, recreational harvests of red snapper in the Gulf of Mexico have often exceeded total allowable catches (TAC) by significant margins under the existing regulations.

This dissertation follows the style of *Land Economics*.

This in turn has also prevented recreation anglers from sustaining a quality fishing experience (Sutinen and Johnston 2003). Recreational red snapper fisheries are closed periodically as a way to ensure total harvests do not exceed the TAC. In 2001 a moratorium was also established on recreational reef fish permits. While restrictions on entry can be effective in reducing fishing pressure, they lead to an inefficient allocation of effort. Such regulations are equivalent to quantity rationing schemes, which have a negative stigma among economists because they may lead to inefficient resource allocation and encourage wasteful rent-seeking behavior.

As an alternative to restricting entry, transferable rights (TR) programs are being increasingly considered in fisheries across the globe. TR programs have been used to address air and water pollution. Under a TR program, rights to use a resource or emit a pollutant can be traded in a market. Many studies such as Montgomery (1972), Anderson (1995), and Carlson et al. (2000) have shown that market-based systems are more efficient than command and control systems because a TR program maximizes the total benefits of the trading participants, regardless of buyer or seller, through transactions of the rights.

In the case of fisheries, TR programs have been implemented with individual transferable quota (ITQs) or Individual Fishing Quotas (IFQs) systems. The way these TR systems work is very simple. Suppose there is a fisherman (angler) who is allocated a right to catch 10 fish. If the fisherman would like to increase his right (or quota) to fish, he can enter the market and purchase more rights, similar to buying some fishing equipment in the store. Once he gets the right to catch fish, he may do so at any time or until the right is expired. This means that he does not have to race to catch the fish before other fishermen catch them. Because the rights can be transferable to any fisherman who wants to fish more, the right ends up being used by the fishermen who value it the most.

The need to study the use of transferable quotas in the for the Gulf's red snapper fishery has recently been noted by the GMFMC's Socioeconomic Panel (GMFMC 1999b). However, examples of TRs in recreational fisheries are few, and the literature appears to be limited. While a number of nations have used transferable quota systems for the commercial sector, including Canada, Iceland, Australia, and New Zealand, the Alaska Halibut charter Individual Fishing Quota appears to be the only recreational TR program in the U.S.[1]

The principal objective of this dissertation is to analyze the possible use of TRs in the red snapper recreational fisheries in the Gulf of Mexico. The overall goal of this dissertation is to comprehensively assess the biological and economic consequences of the red snapper fishery for the TR program and compare the TR program with other management policies. The biological effects will be measured in terms of the red snapper spawning stock by the target year. The positive net present value of surplus (consumer and producer) is used to assess the economic effects for the red snapper TR program and for its comparison to other policies. This criterion implies that a policy is preferable if its net present value of total surplus is greater than that of other policies. In

[1] Currently, a few federal ITQ/IFQ programs exist in the United States: for surf clams and ocean quohogs in Mid-Atlantic and New England waters; for wreckfish along the South Atlantic coast; and for halibut and sablefish in Alaskan waters (FAO 2001).

addition, a policy is regarded as the most preferable one over other policies if its present value of total surplus is the largest.

To conduct the analysis, we propose an economically desirable framework for TR implementation, estimate *mode*-specific recreation trip demand, and find market clearing price under TR program. Fishing modes used in this dissertation include head, charter, and private boats, and fishing in shore. This dissertation focuses on an application for the *recreational* TR system because to date the literature is lacking a fully developed model of how recreational TR program would function. [2] In this dissertation I will, therefore, consider the potential to use TR program to overcome recent difficulties of the recreational red snapper sector.

The specific objectives of the dissertation will be:

(i) To analyze economically desirable institutions and structures to implement TR programs in recreational fisheries.

(ii) To develop a model for the TRs in recreational fisheries. The model of the study, however, will center attention on different unit alternatives such as fish-based, day-based, and pound-based permits.

(iii) To develop an empirically based recreational trip demand that can be linked to a TR permit demand.

(iv) To develop a general framework and a simulation submodel to assess the economic and biological impacts of the TR program.

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[2] Commercial ITQs will be studied only to calibrate General Bioeconomic Fisheries Simulation Model (GBFSM).

The organization of the remaining parts of the dissertation will be as follows. Chapter II will address a background on the use of TRs in fisheries and highlight the limited experience with rights-based programs in recreational fisheries. A brief overview will be provided with the specific rules that govern recreational fishing for red snapper in the Gulf of Mexico. This overview is important for determining how a new approach to regulating recreational fishing will most easily be implemented and accepted when building on existing institutions.[3] Chapter II also will address the critical design issues that must be answered if TRs are to be set up for the recreational fisheries.

In chapter III, an analytical model of the TR program for the recreational sector under different measurement alternatives will be developed and be compared in terms of fishing days, the amount of fish landed per trip, and the angler's utility. This helps address which unit of the TR permit is preferred using specific functional forms for utility and harvesting functions, and various combinations of the parameters. Chapter IV will discuss the recreational trip demand model and will make an application to the Gulf of Mexico recreational fishery. With fully developed TR models, chapter V will address an economic and biological impact of the TR policy using a General Bioeconomic Fisheries Simulation Model (GBFSM). The conclusions of this study will be given in chapter VI.

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[3] This dissertation uses the word *institutions* in this paper to describe "the rules and conventions that define choice sets from which individuals, firms, households, and other decision-making units choose courses of action" (Bromley 1989, p. 39)

CHAPTER II

CONCEPTUAL FRAMEWORK IN TRANSFERABLE RIGHTS

The aim of this chapter is to present an overview of the conceptual framework in transferable rights (TR) and the existing regulations surrounding recreational fishery management. Should transferable permits become legal, they offer the potential to increase overall economic efficiency in both commercial and recreational fisheries by making it possible for the fishermen who value the resource the most to harvest the fish. However, before a system of TRs could be used, there are new variables that need to be considered and questions that must be answered. This chapter will focus on developing a conceptual foundation for the recreational TR system because the literature lacks sufficient discussion of how recreational ITQs would function.[4] We provide an overview of market-based management and then discuss in general terms the advantages of a TR approach to management. We also draw some lessons from hunting programs and applications of TRs in other areas. This chapter, therefore, considers the potential to use TR program to overcome recent difficulties of the recreational red snapper sector.

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[4] The basic theory behind ITQs in the commercial fisheries has been established since Clark (1980) and there is a rich literature that has studied the theoretical and institutional characteristics of these policies.

Rights Based Management of Recreational Fisheries

Transferable Rights - Background

In general, TRs have been studied in depth.[5] Most attention has been paid to environmental TR markets to control air or water pollution. The basic principle in any TR program is that a limited number of rights to use a public resource (such as air quantity or a fishery) are made available to users. There is strong evidence that market-based systems can be more efficient than command and control systems, in which operation sources have less flexibility (see Repetto 2001). TRs offer the potential to increase overall economic efficiency by making it possible for the fishermen who value the resource the most to harvest the fish.

As with any market, a TR market will function properly if the property rights are "complete." Hanley, Shogren, and White (1997) elaborate:

> "Markets will be complete when traders can costlessly create a well-defined property rights system such that a market will exist to cover any exchange necessary. This well-defined property rights system represents a set of entitlements that define the owner's privileges and obligations … (p. 24).

More specifically, they state that the use of a resource will be efficient if the rights are comprehensively assigned, exclusive, transferable, and secure. Because TRs

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[5] In fisheries, the theory is spelled out by, e.g., Clark (1990) and Anderson (1995).

markets are purposefully created by government, it is particularly important that these characteristics be taken into account in their creation.

When applied to fisheries, TR instruments are referred to as individual transferable quotas (ITQs) or individual fishing quotas (IFQ). The general benefits of TR programs in fisheries are discussed by Scott (1989). He identifies three ways that ITQs can be an improvement over existing regulations. The first of these is the advantage relative to the regulation of gear types. When a quota is used, administrators need not concern themselves with gear, net type and so on, but instead focus on the issue of concern: the long-run management of the stock. Second, a quota system removes the incentive for a “race to the fish.” “Far from being a racetrack under close official supervision, [with quotas] a fishery may take on the appearance of a common rangeland, with the owners replacing fishery wardens in checking on each other” (Scott 1989, p. 28). Third, a quota system can be preferred in the management of mixed stocks. As a caveat to this general enthusiasm for ITQs, Clark et al. (forthcoming) have shown that if fishermen anticipate the introduction of an ITQ at some time in the future, all of the economic advantages of an ITQ program can be dissipated by excessive entry into the program in the pre-ITQ period.

A number of nations use transferable quota systems in their commercial fisheries including Iceland, New Zealand, and Australia (FAO, 2001). Batstone and Sharp (1999) provide a thorough review of the New Zealand program of ITQs, which captures most of the important aspects of ITQs. The programs began in 1986 and separate ITQ programs have been established for a number of species and regions. The initial allocations were designated in quantities of allowed catch based on historical harvests, but these were converted to a percentage of the TAC for each fishery in 1990. Batstone and Sharp find evidence that the programs have been quite successful in adding economic value. For example, between 1987 and 1995, the sale price of a permanent right to participate in the area 1 snapper fishery (SNA1) had increased over four-fold and the lease price about doubled. This suggests significant increase in the value of the fishing right to the fishermen despite the fact that the total allowable catch changed little in the period. Moreover, the sale price increased much more than the lease price, indicating a substantial increase in optimism about future profitability in the fishery. Batstone and Sharp also discuss the numerous practical challenges to implementing an ITQ; from recognizing historical rights of the Maori, to managing fisheries outside the ITQ system, implementing an ITQ program is not an easy or costless endeavor.

Consistent with the New Zealand experience, Scott emphasizes that a quota system is not a substitute for regulation, but instead requires reinforcement from government and substantial oversight. In principle, "if the individual quotas exist, their owners can at some cost contract with each other to coordinate them, to perform what are now regarded as government functions (p. 29)." In practice and at least in the short run, government oversight is critical.

Experience with Transferable Rights in Recreational Fisheries

The National Research Council (1999) recommended that attention should be given to the implications of recreational participation in fisheries, and to consider the potential application of ITQs in recreational fisheries. The literature and experience with TR in recreational fisheries, however, appears to be quite limited. Sharp (1998) provided some initial ideas about how a recreational TR program might be structured and addressed some of the practical issues regarding allocation and monitoring. Sutinen et al. (2002) and Sutinen and Johnston (2003) provide more in depth discussion and discuss the existing examples of such programs.

Sutinen et al. (2002) study in detail the program proposed for the Alaska halibut fishing since it is “the sole U.S. template for the design of joint commercial-recreational rights-based management” (p.9). In response to the success of IFQ management in the commercial sector, the North Pacific Fishery Management Council (NPFMC) approved an IFQ program for the halibut charter fleet in Southeast and South-central Alaska on April 14, 2001. However, as of June 2006 the program has not been implemented because there are some practical issues to be solved. The IFQ program is expected to replace the Guideline Harvest Level (GHL) program proposed by the NPFMC in February 2000 (NPFMC, 2001a).

The NPFMC report summarizes major features of the approved charter IFQ program as follows (2001a): the program does not change the 2-fish daily bag limit or the 2-day possession limit for charter anglers. The charter quotas are issued to charter owners, or to people who leased a vessel from an owner and who carried clients in 1998 or 1999 and 2000. The Charter IFQ is allocated 125% of the average 1995-99 charter harvests, but these allocations may grow over time. The charter IFQ would be integrated into the existing commercial IFQ program and would be equal to about 13% of the combined commercial and charter quota in Southeast Alaska and about 14% of the combined commercial and charter quota in South-Central Alaska (NPFMC, 2001a).

Several additional elements of the charter IFQ program are included in the summary of NPFMC (2001a) addressing practical issues such as measurement unit of TRs, transfer between commercial IFQ and the charter IFQ, and limitation of the Alaska charter IFQ program:

- The proposed unit of recreational IFQs is the number of fish, in keeping with current regulations.
- Charter quota shares may not be sold to the commercial sector but commercial shares, which are issued in pounds, may be transferred to the charter sector, translating pounds to fish based on average weight.
- The program does not affect non-charter recreational anglers.

The charter industry has indicated concern that the IFQ system would increase charter fishing prices and about enforcement because traditional methods used to enforce commercial IFQs, might not be directly applicable to the recreational sector (Sutinen et al. 2002).

As with any TR program, there are many practical issues that must be addressed and these are evident in the minutes of the NPFMC's committees (NPFMC 2001b and NPFMC 2003a). For example, in 2001, enforcement issues such as prior notice of landings, offload window, vessel clearance requirement, and shipment report were considered (NPFMC, 2001a). The NPFMC submitted the analysis of the charter IFQ program to NMFS in May, 2003 and the following approval process was anticipated:

Secretary of Commerce adoption in 2004; program development by NMFS in 2005 including calculation, distribution, and appeals; and one year delay between the issuance of quota and fishing to examine the geographic distribution of quota in 2006. It is anticipated that the Alaska halibut charter IFQs may be in effect in 2007 (NPFMC 2003b), although Criddle (2006) reports that the program was rescinded and, therefore, will not be implemented.

The Alaska halibut charter IFQ program is an important example because, despite the fact that it will not be implemented, it was the first attempt to implement TRs in recreational fisheries. As IFQ programs are developed in other regions, the design issues addressed in this program will provide valuable lessons about issues of initial allocation, unit of rights, and transferability between sectors.

Wildlife Market – Recreational Hunting and Fishing

As noted above, there are few examples of recreational fishing TRs. In this section, some applicable lessons from all the wildlife resource markets including hunting are explored. The use of wildlife resources is often dependent on market forces, which implies that demand and supply work for determining an allocation of wildlife services through the market clearing price of the service. The wildlife market is a big part of the economy in US. According to 2001 National Survey of Fishing, Hunting and Wildlife Associated Recreation (US Fish and Wildlife Service 2002), anglers spent $35.6 billion in 2001 including other trip expenditures such as licenses, stamps, tags, and permits which cost anglers nearly $0.6 billion. In the case of hunting, of the $20.6 billion spent by hunters in 2001, other trip expenses such as licenses, stamps, tags, permits were $0.7 billion (3.4 percent of all hunting expenses). Hunting and fishing are similar representative examples of outdoor leisure in that permits/licenses for both activities are required. Because of the similarity of market mechanisms between hunting and fishing, investigating specific wildlife markets will help a newly developed TR market in recreational fishing to be successfully implemented by providing prosperous schemes.

Hunting Permit Market

Although there is a lack of examples of TR program in recreational fishing, lessons about the management of a potential fishing TR program can be drawn from the experience with TRs for hunting. Among hunting permit markets, the Kansas nonresident deer hunting program is noteworthy because permits are transferable.

Before 2000, a limited number of nonresident hunting permits for deer were drawn only to non-resident hunters by lottery. In 2000, Kansas began issuing about half of the nonresident deer hunting permits to residential landowners and tenants/managers. Although hunting takes place on private land, the deer that roam the land are a publicly held resource and it is the right to exploit that resource that is distributed in the Kansas program. The notable feature in the new deer hunting permit is *transferability*. Recipients of the permits can use the permit for themselves or transfer the permits to another hunter. All transfers must be reported to the Kansas Department of Wildlife and Parks (KDWP) main office by mailing a transfer form or through online processing. Because the dates of the specific season are assigned, there is a limited duration on the permits, meaning that permits cannot be stored for future use. This new TR program set up well established property rights that create a competitive market in recreational hunting (Taylor and Marsh 2003). Unlike some hunting lotteries, those who are granted a right in the Kansas lottery are required to make a significant payment, equal to $322 in 2006.

The introduction of this program drastically increased demand for non-residence permits. Table 2.1 shows data from Marsh and Taylor (2002) associated with permits available, the number of applications, and permits drawn. Notice the change that occurred in 2000 was accompanied by a substantial increase in the number of permits available; to nearly 15,000 in 2000 before dropping back to 7,800 and 7,500 in 2001 and 2002. These figures are more than double the 1999 number. Between 1999 and 2002 there was also a three-fold increase in the number of applicants, suggesting that the value of the permits grew substantially between 1999 and 2002.

TABLE 2.1

Kansas Department of Wildlife and Parks Nonresident Deer Draw Data

Year	Permits Available	Number of Applicants	Permits Drawn
1999	3,476	5,041	3,199
2000	14,987	8,519	8,139
2001	7,804	12,440	7,793
2002	7,581	16,991	7,596

Source: Marsh and Taylor (2002)

Although the state collects fees from lottery winners, recipients of the rights have an opportunity to profit by selling permits to hunters. Based on a 2002 KDWP survey of hunters, Taylor and Marsh (2003) report that the mean price of non-residence deer hunting permits for all hunting modes was \$760.13, which is high compared with the cost of a permit in the random draw lottery to the landowners of \$205.5 during this period. However, the sales price was often bundled with other services including access to the land, guide services, etc. Using Taylor and Marsh's regression analysis evaluated at the mean of all variables other than guide services, we find that on average hunters who did not pay for guide services paid \$656 for the permit, further reduced to \$82 if they made use of land that did not require negotiating access with the landowner. Based on this analysis, it appears that the hunting rights alone had an average value of about \$573. The resale market for these permits appears to be quite active. Although in the sample period only 2% of the licenses were purchased via the Internet, it is now possible to find a number of permits for sale on , indicating that the market is becoming much more fluid. Still, the web site of the Mid-America Hunting Association (http://www.mahadeer.com/, 8/17/2006) reports that hunters can obtain permits from the secondary market at low cost, though "time frame to shop for a tag is much longer." The market has changed since 2002; in 2006 the supply of permits for a number of regions in the state exceeded demand and there were surplus permits available from the state at the fixed price of \$322. At least for those areas, it is unlikely that 2006 permits will sell for much above the government set price.

Aspects of TRs are also present in several other hunting programs in the U.S. that provide incentives to voluntarily conserve huntable species. California and Colorado were the first two states to implement incentive-based programs in hunting, California in 1984 and Colorado in 1985. California's Private Lands Wildlife Management Program (PLM) allows landowners to increase the bag limits on their land or to sell tags or permits directly to hunters. To qualify, landowners must improve wildlife habitat. Colorado's Ranching for Wildlife Program is similar to California's PLM. Landowners can raise hunting quotas on their land and achieve revenues from fee hunting after they agree to adopt state-specified habitat management guidelines (Freese and Trauger 2000).

Texas is thought of as one of the most remarkable fee-hunting regions in U.S. because more than half of the ranches in Texas offer fee hunting (Freese and Trauger 2000). In 1998, Steinbach et al. estimate that Texas landowners earned $100-300 million from hunting fees and current levels are expected to be much greater. Fee hunting on private land in Texas might advance biodiversity as owners attempt to raise revenues by increasing the number of huntable species (Teer 1997). These fee-based hunting programs in these states grant rights to sell or lease to private landowners and consequently encourage conservation in habitats and species.

Although some features of the hunting programs may not be directly applicable to TRs for fishing, the programs reviewed in this section provide some good lessons. Like fishing, hunting involves the exploitation of a public wildlife resource for personal recreation. Like fishing, observing the participation of every participant is difficult, though in both cases licenses are required which can be used to obtain information that will make the market function more smoothly. Although policy makers are usually reluctant to create opportunities for profits from public resources, the Kansas program encourages such profit making. At the same time, however, the government set price has increased prices so that larger shares of the rents are now captured by the state. The Kansas program may have been more politically palatable because it applied to *non-resident*; no similar market exists for the resident permits. The Colorado and California programs are useful examples of how TR programs can create incentives for conservation. Finally, the experience in Texas demonstrates that it is possible to have a nearly complete free-market approach to hunting rights. It appears that at least some of these markets are functioning with relatively low transaction costs, evidenced by trading being carried out on the Internet.

Recreational Fishing Market

Recreational fishing markets are found mostly regarding fishing licenses, stamps, and tags for big fish. As mentioned earlier, $0.7 billion was spent in 2001 to buy licenses, stamps, and tags. Although these are restrictedly transferable from the state governments or legitimate agents (e.g., mostly big groceries and outdoor stores, to fishermen), these markets have been well managed. The Tarpon tag program used by some states is most similar to a form of IFQs/ ITQs that are currently proposed. For example, Alabama Tarpon tags can be purchased at $51 per fish. Unless a person purchases a tarpon tag, he is not allowed to kill, possess, and harvest tarpon from the public waters of the state of Alabama. The tag is valid for one year from date of purchase. However, this program is not commensurable with a real market since transferability and feasibility is not perfectly acquired in these markets.

In spite of underdeveloped right-based markets in recreational quotas/permits, a *quasi-market* in the private sector has been created by establishing nonprofit organizations such as Trout Unlimited. Individuals interested in conserving fish and fish habitat can do so by investing in nonprofit organizations. For example the North Atlantic Salmon Fund in Iceland, Greenland, spent approximately $6 million to purchase more than 4,000 tons of commercial quotas, between 1989 and 1998 (Freese and Trauger 2000).

We have explored market-based tools to manage wildlife resources such as hunting and fishing. The use of wildlife resources is thought of as a privately provided public good (not free to use). Because it is hard to assign well defined property rights for wildlife resources including fisheries, it is more complicated to use the market-based mechanism in wildlife management than in normal products such as concert tickets. Nevertheless, considering wildlife resources from a market perspective may provide a better means to measure the value of the wildlife services and help to find an efficient economic solution to conserve wildlife activities. We now turn specifically to the practical questions of implementation that must be addressed if a TR program is to be designed for a marine recreational fishery.

Existing Institutional Structure

Before a TR program for the Gulf of Mexico red snapper fishery can be considered, it is important to first be aware of the existing institutional structure.

Red Snapper Recreational Fishing in the Gulf of Mexico

Red snapper recreational fishing regulations are based on the Reef Fish Fishery Management Plan (RFFMP) which was developed by the Gulf of Mexico Fishery Management Council (GMFMC) in 1984. It has been revised by 21 regulatory amendments to overcome overfishing and to pursue sustainable fisheries in the Gulf of Mexico. Until now, the main control tool for red snapper fisheries has been the total allowable catch (TAC). GMFMC (2000) defines the TAC as “a level of fishing intended to obtain optimum yield (OY) and to prevent overfishing, or to follow a recovery plan when a stock is overfished. Annual changes to the TAC or measures to attain it are implemented through a regulatory amendment.” The Council sets a level of TAC from within the acceptable biological catch (ABC) range which is intended to stop overfishing or achieve sustainability of the fisheries.

Table 2.2 presents changes in the regulations that govern red snapper fishing in the Gulf of Mexico from 1991 to 2003. The official TAC of the recreational sector was 1.96 million lbs in 1990 and increased to 4.47 million lbs in 1996 where it remains today. The TAC was not enforced until 1997 through recreational sector (Hood and Steele 2004). Recreational harvests of red snapper are estimated to have often exceeded the TAC by significant margins, while commercial sector correspond with the TAC (Sutinen and Johnston 2003). The recreational red snapper fisheries reveal patterns in which open days have decreased over time. The first closure of the fishery took place in 1997 when the season was ended in late November. From 1990 to 1996, Gulf of Mexico red snapper fishery open days were 365 but decreased to 330 days in 1997 and only 194 days in 2003 (Hood and Steele 2004). The decreasing season length is the most important trend in recreational red snapper management.

TABLE 2.2

Changes in Recreational Red Snapper Regulations

Year	Size Limit (Inches, Total Length)	Daily Bag Limit (Number of Fish)	Season Length (days)	Recreational Allocation/Quota (Million lbs)	Recreational Harvest (Million lbs)
1993	13	7	365	2.94	5.29
1994	14	7	365	2.94	4.26
1995	15	5	365	2.94	3.25
1996	15	5	365	4.47	3.57
1997	15	5	330	4.47	5.41
1998	15	4	272	4.47	5.76
1999	15	4	240	4.47	5.51
2000	16	4	194	4.47	3.92
2001	16	4	194	4.47	4.52
2002	16	4	194	4.47	5.32
2003	16	4	194	4.47	4.58
2004	16	4	194	4.47	5.08
2005	16	4	194	4.47	4.59

Source: History of red snapper management in federal waters of the U.S. Gulf of Mexico -1984-2004: 2004 Red Snapper SEDAR, NOAA Fisheries, SEDAR7-DW-40 (Hood and Steele, 2004) Harvests data for 2004 and 2005 are from Vivian Matters (Personal Communication, 8/15/2006).

Two additional regulations used in the red snapper recreational fishing are size limits and bag limits.[6] Recent regulatory amendments show a pattern of smaller bag limits and increasing minimum size in the recreational sector. The RFFMP in 1984 established a minimum size limit of 13 inches total length (TL) for red snapper with the exceptions that for hire boats were exempted until 1987 and each angler could keep 5 undersize fish (GMFMC 2000). As of 2005 the Council has set the recreational red snapper bag limit at 4 fish and set the recreational red snapper minimum size limit at 16 inches TL.

Figure 2.1 presents the distribution of recreational trips recorded in each of six two month “waves” that were recorded in the 1997 Marine Recreational Fishery Statistics Survey (MRFSS). The MRFSS data do not measure the relative portions of angler participation throughout the year, but it is clear that fishermen do indeed participate year round.[7] The figure also shows the dates that the red snapper fishery has been closed in recent years and we see that the current closure dates, between November 1 and April 20, correspond to times when many anglers used to fish. It appears, therefore, that the closure is inefficient because anglers cannot fish in the months that they would prefer.

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[6] These fishing regulations are most commonly used in recreational fisheries. A bag limit is a mandatory restriction that places an upper limit on the number of fish an angler can retain during a fishing trip. A size limit is a regulation such that an angler can retain a fish only of it exceeds a minimum size.

[7] The data presented include all gulf fishing trips. The 1997 MRFSS data include 42 observations from anglers who targeted red snapper. Trips by these anglers are also distributed quite evenly throughout the year.

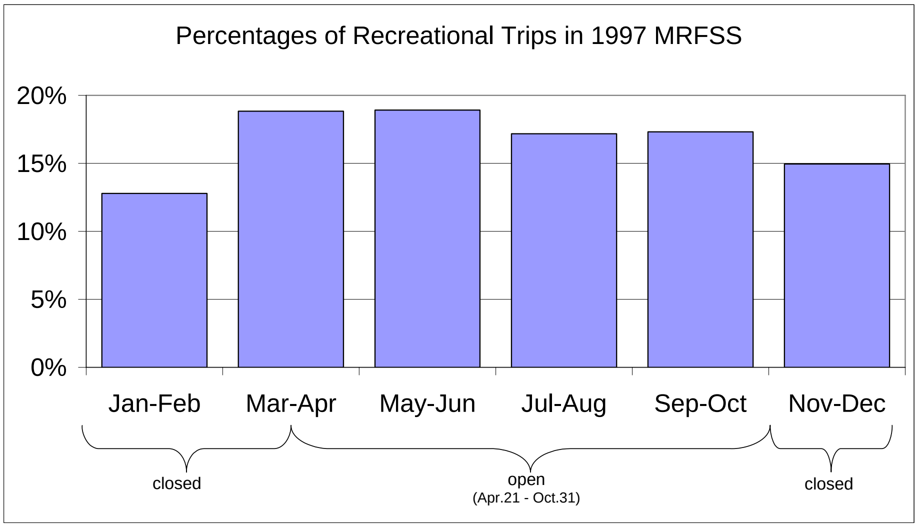

FIGURE 2.1

Open Season in 2005 and Distribution of Recreational Trips in 1997

Fishing Regulations and Rules in the Gulf States

Table 2.3 presents a summary of the regulations that govern red snapper fishing in the Gulf of Mexico in 2005. It is notable that the fishery is already under relatively tight restrictions in terms of the size and bag limits, and season closures. The introduction of a TR program in the fishery would amount to a requirement that anglers possess an additional authorization in order to fish for red snapper.

In all states in the Gulf, anglers are currently required to hold a license, but it appears that only in Texas is an additional red snapper stamp required, and that stamp is valid for the entire red-snapper season. Hence, the introduction of a requirement that anglers purchase a right to fish on a given day, would be rather new. However, short-term rights are not unfamiliar in management of hunting and fishing as discussed above.

Three- and five-day non-resident hunting and fishing rights are routinely issued in many states, often at rather substantial fees.[8] Although residents may resist the loss of their entitlement to fish whenever they choose, the implementation of such a program would not be entirely new and enforcement could be handled in the same fashion that license requirements are currently enforced.

Critical Questions in the Designing a Transferable Rights Market for a Recreational Fishery

In this section we will consider ten practical questions that must be answered before a TR program could be established for a recreational fishery. The answers to these questions are not independent, but each must be addressed. Two or more alternatives exist for each question and none have obvious answers. We close in the following section with a proposed program for a TR program for the Gulf of Mexico Red Snapper (GRS, hereafter) fishery that answers these questions. All the questions elaborated in this section are not testable hypotheses but we provide the most preferable schemes after reviewing some lessons of existing market-based programs and considering the characteristics of recreational fishing in the end of the section.

[8] For example, Arkansas charges $100 for a Nonresident 3-Day All Game Hunting License (http://www.arkansasstripers.com/arkansas-hunting-fishing-license.htm).

TABLE 2.3
Recreational Saltwater Fishing Regulations 2005

	LICENSE	STAMP	SIZE LIMIT	BAG LIMIT	SEASON [g]
FEDERAL [a]	State License Required		16 in. TL	4 / person	April 21- October 31
TEXAS [b]	annual: 1yr (R & NR) trip: 3day,14day(R) & 5day(NR) lifetime-n/a	Saltwater Fishing Stamp Endorsement Required	15 in. TL	4 / person	"
FLORIDA [c]	annual: 1yr (R & NR) & 5yr (R) trip-3day, 7day (NR) lifetime: (R only)		20 in. TL(Atlantic) 16 in. TL (Gulf)	2 / person (Atlantic) 4 / person (Gulf)	"
MISSISSIPPI [d]	annual: 1yr (R & NR) trip-3day (NR) lifetime-n/a		16 in. TL	4 / person	"
LOUISIANA [e]	annual- 1yr (R & NR) trip: 1day,4day (NR) lifetime: (R only)		16 in. TL	4 / person	"
ALABAMA [f]	annual-1yr (R & NR) trip-7day (R & NR) lifetime-n/a		16 in. TL	4 / person	"

Sources :a. Gulf of Mexico Fishery Management Council(http://www.gulfcouncil.org)
b. Texas parks and wildlife Department(http://www.tpwd.state.tx.us)
c. Florida Fish and Wildlife Conservation Commission (http://myfwc.com)
d. Mississippi Department of Marine Resources (http://www.dmr.state.ms.us)
e. Louisiana Department of Wildlife and Fisheries (http://www.wlf.state.la.us)
f. Alabama Department of Conservation and Natural Resources -Marine Resources Div. (http://www.dcnr.state.al.us/MR)
g. Vary annually

Note : R - Resident, NR - Non-Resident, and TL - Total Length

How Should Transferable Rights Be Measured?

In designing a TR program for recreational fisheries, the first question that must be answered is the units of measurement in which the rights will be denominated. Dales (1968) referred to this as the "asset-unit," defined as "the smallest physical amount of the asset to which it is practicable to apply property rights" (p. 797). In the recreational fishery TR program, it may be difficult to determine an asset-unit because of biological characteristics, i.e., fishing mortality when fish are released, and individuals' different fishing preferences. However, three alternatives seem to be apparent:

Alternative 1: Set the unit of transferable rights in number of fish retained.

Alternative 2: Set the unit of transferable rights in pounds of caught fish.

Alternative 3: Set the unit of transferable rights in fishing days.

Following on Dales (1968), the question that must be asked of each of these options is, what is "practicable"? To answer this there are three issues that must be considered: control over the biological impact of the fishing activity, monitoring and enforcement, and transaction costs.[9]

Under alternative 1, a single right would grant its holder a right to harvest one fish (presumably of legal size if size limits are retained). This alternative is the approach that has the most in common with the TR programs discussed above. For example, the Alaskan halibut program is specified in number of fish and the Kansas hunting program

[9] In chapter III we carry out a theoretical comparison of the welfare consequences of alternative right specifications. In that analysis we find that there is no clear winner across the three alternatives.

is for a single deer. Although there is some uncertainty due to the size and age of the fish that might be harvested, a permit based on number of fish relates quite well to the biological impact that anglers impose on the fish stock. Monitoring and enforcement would need to be addressed in a way that ensures easy compliance without creating perverse incentives. As with bag limits, a right denominated in fish creates a moral hazard problem. This problem occurs because if a recreational angler buys such a right permit he or she has an incentive to discard caught fish (that may not survive) so that the right is essentially used several times. These issues are not a major problem in big-game hunting. But it would be much more difficult in a deep sea fishery with anglers regularly catching several fish and several species in a single day. On the other hand, Sutinen et al. (2002) point out that the rights granted to the recreational fishery in the Alaskan Halibut program are denominated in fish to be as consistent as possible with existing regulations. Hunting permits are routinely set as a single animal (e.g., the Maine Moose hunting program and Turkey permits in most states). A desirable feature of any such system would be that the right would need to be terminated immediately after a fish is landed by an angler. However, it is not clear to us how this could be ensured in a deep sea fishery. Rights specified in terms of fish would need to be purchased in advance of a trip and the right would probably need to take a physical form such as tags used in many hunting and some fishing programs. Because of uncertainty about how many fish an angler will land, anglers would either need to have a surplus number of rights before each trip and resell them afterwards, or buy too few rights and essentially face a small bag limit.

Under alternative 2, rights would be stated in terms of a number of pounds. This approach would specify the TR in the same units as the official TAC, facilitating an understanding of the impact on the fishery each time the right is used. This would also reduce the incentive to discard undersize fish as compared to the per-fish permit since these would use up less of the angler's right. The pound-based permits will also facilitate transferability of rights between sectors without translating other units (fish or days) into pounds because most commercial ITQ/IFQ are denominated in pounds. Still, because most anglers will purchase relatively few permits and the stochastic nature of fishing exists, the limit on pounds might cause anglers to discard fish in order to come close to using their complete right. As with alternative 1, monitoring and enforcement would require that rights be purchased before a trip the problem of ensuring that an angler has sufficient rights would be a burden on anglers and could lead to discards once an angler has run out of rights. Finally, unlike the one-fish one-right approach under alternative 1, there is no obvious way that an angler would terminate his or her right upon landing a fish. Transaction costs, therefore, are likely to be higher under this alternative.

Under alternative 3, rights would be stated in terms of a number of days for fishing. This approach is the least satisfactory in terms of its relationship between rights used and the physical impact on the fishery since fishing mortality depends on the angler's success. If the TRs are denominated in terms of days of access to the fishery, then bag limits would probably need to be used to control total catch per day. As with TR for nonpoint pollution, this alternative essentially represents a *practice-based* allocation, with its ensuant limitations. In this case inefficiency arises because some anglers may not desire a complete bag limit while others may wish to exceed that limit. In spite of their known inefficiencies, practice-based TRs are used when monitoring of actual environmental impacts is costly and incentives exist for noncompliance. This may be appropriate here. The use of rights stated in days of access could also have advantages in terms of monitoring and enforcement; the day-based right could be enforced in much the same way as requirements that anglers have a fishing license. Although anglers know that it is unlikely that their license will be checked during a day of fishing, they usually purchase the license before fishing because of the uncertainty as to whether they will be caught. A day-based right would, therefore, be used before the fishing day is begun. This would mean that it could be monitored through an electronic tracking system in which an angler can purchase, sell, and terminate a right through the Internet or a toll-free telephone number.

Who Should Hold Rights?

The next question that must be answered is what organizational unit might hold rights. Traditionally in TR programs, rights have been primarily held by individuals, e.g., individual polluters or individual commercial fishermen. At first glance, one might assume that the answer to this question is obvious – rights should be held by anglers. However, Sutinen and Johnston (2003) propose a novel alternative, arguing for the use of Angling Management Organizations (AMOs) that would manage and distribute the rights back to anglers. In their proposal, AMOs, consisting of groups of anglers, would be allocated the rights, and they would then determine how those rights would be distributed to individual anglers. They propose that anglers would purchase the right to fish by purchasing shares, which "may be bought and sold much like shares of companies" (p. 478).

Alternative 1: Individual anglers

Alternative 2: Angling Management Organizations

Alternative 3: For-hire recreational sector only

Alternative 4: Local or regional governmental authorities

As noted by Sutinen and Johnston (2003), alternative 1 offers many advantages because of its connection to existing regulatory structure. However, they raise two main concerns about this approach: initial allocation issues and the question of enforcement. The first of these will be discussed below. The latter is closely related to the units in which rights are stated and, as we note above, this might be reduced by using a practice-based right, avoiding the need to monitor harvests ex post.

The AMO option favored by Sutinen and Johnston (2003) would allocate the rights to groups of anglers. The AMO could distribute the rights back to anglers, or they could engage in more creative management options, such as arranging lotteries of rights, tournaments, etc. As the holder of the rights, the AMOs would be responsible for monitoring harvests by anglers and it would be the AMOs rather than the anglers that would report actual harvests to the government. The authors believe that this could have economies of scale, reducing enforcement costs. The AMO is also more likely to engage in activities that lead to improvements in the fishery, much like holders of ITQs sometimes participate in stock improvement activities (Repetto 2001). In the end, however, it is individual angler behavior that must be monitored, so that unless responsibilities are clearly defined and the AMO is able to make better use of information, the AMO approach may simply add an additional level of bureaucracy without any reduction in cost. Sharp (1998) notes that when proposed in New Zealand, the AMO approach was not adopted in part because of its inconsistencies with legal authorities of management councils.

Alternative 3, in which the TRs would be held only by the for-hire recreational sector, is the system that has been proposed for the Alaskan halibut fishery. This approach has advantages in terms of monitoring and initial allocations. However, since this would leave the non-charter fishermen out of the program, it is only appropriate if charter boats dominate the recreational fishery. Further, there must still be some control over non-charter anglers, since this approach would create an artificial cost advantage to non-charter fishing, which could lead to growth in that type of fishing.

Under alternative 4 the TR would be allocated to local or regional governmental authorities. These could function in much the same way as AMOs, with some of the same advantages. However, in many ways this is not that much different from the status quo and not likely to yield improvements unless the regional authorities adopt some form of TR program themselves. Moreover, for migratory species, lack of enforcement by one governmental authority would have consequences for the other regions.

How Should Temporal and Spatial Elements of TRs Be Handled?

In specifying the units of the TR, their spatial and temporal characteristics must also be defined. Does a recreational TR grant its holder rights to use the fishery at any time and in any place, or in a limited region for a limited time period.

Alternative 1: Rights would not expire and could be used anywhere within the fishery

Alternative 2: Rights would expire and/or would be valid only in specific subregions

First, we consider the spatial dimension: would permits be valid in all Gulf waters, or would the TAC be allocated across the states or even smaller regions? Based on the simplest conception of economic efficiency, economists would typically argue for no spatial limitation so that rights could go to those areas where the permits are most valuable. There are two reasons that spatial limits might be imposed. First, there may be equity considerations and if, for example, the vast majority of the permits were purchased for use in a single state, this could adversely affect the remaining states. Hence, political forces may push for a fixed allocation across states. A second reason is biological: as pointed out by Sutinen and Johnston (2003) if rights became highly concentrated this could lead to localized stock depletion.

With regard to the temporal dimension, there are two issues that must be resolved. First, how long a permit would be valid – e.g., would unused permits expire at the end of the year? There is strong evidence that such expirations would be counterproductive (Hahn and Hester 1989) as they would encourage use at the end of the year when delay would actually be preferred for both by the anglers and in terms of the biological health of the fishery. There is, however, precedent for a time-limited right; to our knowledge in most hunting permit programs in which the duration of use is specified, unused permits expire at the end of the specified date and (although we are unable to find any valid reason) the recently proposed IFQ program for the GRS commercial fishery program has a similar provision. The second issue is how to control how long a permit would be valid for use. This is obvious if rights are specified in terms of a day of fishing. But if rights were specified in terms of fish or pounds, then it is less clear: Suppose there is an angler who intends to use up a 10 pound permit in his trip but he catches only 5 pounds of fish. Can the unused 5 pound rights be valid? We see advantages to specifying the right as an ex ante right – i.e., a right gives you to capture up to one fish, though not the guarantee of that. This approach would mean that rights could be tracked and exchanged electronically without the use of a physical tag. On the other hand, in keeping with most hunting tag systems and commercial ITQs, quantity-based rights would be valid until the fish are actually captured.

How Should TRs Be Allocated Initially?

The question of initial allocation is one of the most problematic and studied issues that must be addressed in developing any TR program. When TRs are used in pollution markets, it is common for rights to be “grandfathered” to sources based on historical emissions. However, this is not the only possibility and it may not be a practical alternative in the case of a recreational fishery.

Alternative 1: Grandfathering based on historical use.

Alternative 2: Lottery

Alternative 3: Auction

Alternative 4: Federal sale (retail at fixed price)

Under alternative 1, TRs can be initially allocated by historical catch records of all eligible applicants who owned or operated a vessel. Individual anglers who keep fishing licenses and stamps for red snapper fisheries for a certain period could obtain an initial allocation of the TRs. Because of the large number of anglers and the lack of records, this system would be very difficult. The difficulty in establishing grandfathered rights is one of the reasons that Sutinen and Johnston (2003) argue that rights should be issued to regional AMOs. An interesting aspect of grandfathering that should not be ignored is that the process of determining the allocation can create an incentive for historical users of a resource to reveal their use (Montero et al. 2002). On the other hand, the critique of Clark et al. (forthcoming) is specifically related to grandfathered rights and policy makers should watch for expansions in efforts prior to the establishment of a TR program with grandfathered rights. This not only determines who will receive the right, but can help establish a system for monitoring future use.

Like grandfathering, if the initial allocation of TRs is established through a lottery the rights are typically given away at no cost to those that receive that right. This approach is followed in many recreational systems in which the supply of available use rights is less than the demand. Applicants could apply separately, perhaps at a fee, for access rights, or all licensed anglers could automatically be qualified. In cases like the GRS fishery, in which there is a substantial presence of charter and “party” boats, a separate lottery to those vessels might needed to avoid too much dispersion of the rights.

Scrogin and Berrens (2003) note that lotteries are prevalent in the United States including the Maine Moose hunting permits, the Kansas nonresident deer hunting permits, and a New Mexico lottery system for elk harvest rights. They emphasize that "since lotteries ration independently of income, they are commonly favored by the public due to equity concerns (p.137)." Note, however, that as in the Kansas nonresident hunting permit program, a lottery does not have to give the right to winners at no cost, but can instead give winners the right to buy that right at a non-trivial cost.

Alternatives 1 and 2 grant the TRs to the users, (typically) at no cost. This is not the only way that the initial allocation can be determined. Under alternative 3, the TRs permits would be initially distributed to the public through an auction. Auction participants could include not only individual users, but also retail shops, charter boat operators or groups of angler. Auctions are frequently used to transfer assets from public to private hands, as in timber rights and off-shore oil leases, and when the seller is unsure about the values that bidders are willing to pay. They also have the advantage of transparency, which is important in such transactions. Economic efficiency of the auction in the initial allocation of fisheries TRs might, however, depend on the detailed mechanism of the auction.

Morgan (1995) argued that the method of initially allocating fisheries quotas will eventually move to auctions because quota allocation by administrative decision is economically inefficient. He said that auctions offer two significant advantages over other alternatives of resource allocation. First, the process is economically efficient due to readily identified market demand and appropriate price for quotas. Second, the process identifies those potential users who place the highest values on fishery in question. Using auctions to allocate initial fisheries TRs might be better than using other alternatives because it identifies potential fishermen with the highest use value of the fisheries and maximizes revenues in an economically efficient way and facilitates the purchase of multiple permits by the for-hire sector.

The final option would be to sell the licenses at a fixed price. For example, in the red snapper case, rights might be held throughout the year by the GMFMC or National Marine Fisheries Service (NMFS) and sold directly to the public. A disadvantage of this approach is that the fixed price could create opportunities for rent-seeking behavior if the price chosen by the agency is too low. If the set price is too low then demand would exceed supply. In this case a secondary market would arise, creating opportunities for profiteering by those able to game the system and purchase their permits early. If a fixed-price approach is taken, governments may feel compelled to regulate transfers in a manner that diminishes the potential for the market to efficiently allocate the permits. A creative adaptation to this that could overcome many of the problems would be to have a government price that varies in response to supply and demand.

The first two options considered above would allocate the TR to the public at relatively low cost. This has been favored in many TR program as the most politically palatable approach. However, it is not necessarily the only option. The Kansas permit program charges relatively high prices for hunting permits, so high that in 2006 supply exceeded demand. In a TR program for the GRS fishery, it is likely that prices, at least initially would not be exceedingly high.

Should Trades of TRs Be Monitored?

With the exception of products like military weapons and dangerous chemicals, most goods are transacted in markets with no monitoring of each trade. This is not true in many TR markets. TRs are essentially a government granted right to exploit a public resource so it is usually, though not always, the case that the government must be informed of TR trades.

Alternative 1: Rights could be sold and traded with agency notification

Alternative 2: Rights could be sold and traded without agency notification

Under alternative 1, all trades should be reported to a government agency such as GMFMC or NMFS. For example, in case of the Kansas nonresident deer hunting permit program, all transfers are processed through the KDWP main office. Alternative 2 is an option only if the right takes a physical form such as a card or a tag. Even if the right takes a physical form, enforcement of transfer restrictions would be difficult or impossible since there would be no monitoring of the rights permit trades. The benefit of notification is that it facilitates enforcement of the overall cap and allows better monitoring of fishing. The costs of such monitoring are related to transaction costs and some loss in privacy. We believe that if all trades are carried out electronically transaction costs might be kept low and monitoring of the program will be improved.

Where Will Trade Take Place?

Regardless of how the initial allocation of rights is made, efficiency requires that trades be possible. Although economists frequently assume that a market will arise naturally, in designing the market planners should consider whether they want to make any efforts to help that market take a specific form.

Alternative 1: Trades take place in retail markets

Alternative 2: All sales made by government

Alternative 3: Clearing House

Transferability of rights requires the development of a market. Under alternative 1, retail shops would be able to sell or buy rights. These could be sporting goods stores, bait and tackle shops, grocery stores, etc.; or transactions might take place between private parties, for example through ebay. Most current shops where fishing licenses are sold would be a potential outlet for the sale of transferable rights. If rights take a physical form, then retail distributors would be a very useful. However, to avoid localized scarcity, it would be helpful to have a computer generated supply of the rights as is done with lottery tickets.

Under alternative 2, the rights would be sold only by government agencies. This would have the advantage of transparency and avoid the impression that private parties are profiting from a public resource. However, governments are typically not very good at setting prices so as to balance supply and demand in the market place; it is almost certain a government run market would not equate supply and demand. For example, if the price is set too low, then demand would exceed supply, inefficient rationing would result and extra-market, possibly illegal, trades would be likely. Although it runs counter to most government approaches, it might be possible for the government to play the role of a market maker with prices varying over time in response to supply and demand pressures.

Finally, a government sanctioned, but not necessarily run, clearinghouse might be possible in which rights would be transacted. This approach would only work if rights do not take a physical form. In that case, all market transactions could be achieved through bilateral negotiations, though price information would be assisted by a bulletin board and notification of prices of recent trades.

Will Speculation Be Allowed?

An issue related to the two previous points is whether or not retailers and resellers will be allowed to sell the TRs at a profit. Fishing licenses are typically sold at a fixed price determined by the government with the seller usually receiving regulated issuance fees. Since such licenses are not scarce, this approach is reasonable. However, if a TAC is to be allocated through a market, efficiency requires that the price be allowed to vary depending on supply and demand. Occasional spikes in prices are possible in a market, and this could lead to public outcry and opposition to the TR system. We believe, however, that with the advent of ebay and similar online markets, the public is increasingly comfortable with the trading of a wide variety of assets and forces of supply and demand are more responsive than ever, which should have the effect of mitigating price variability. Further, there is precedent for such resale and speculation on TRs in the Kansas program, where the resale price charged by sellers in the 2001-2002 period was more than $200 higher than the price originally charged. In Kansas this appears to have occurred with little public outcry, though the fact that it is only the *non*resident permits that are transferable might have something to do with this.

The problem with speculation arises when individuals are able to capture a market and thereby make exploitative rents from sales. If a large market is considered, as for the GRS case, the potential for market wide monopoly power seems slight. Under an AMO type structure, oligopoly power could arise, and this would need to be monitored if this approach is used. A more serious concern is that localized scarcity might exist if rights take a physical form that cannot be moved quickly from one place to the next. If, on a given Saturday morning, the number of anglers wishing to buy rights at a single location exceeds the available demand, the prices could soar rather quickly. These kinds of local pressures can be avoided if rights are transacted electronically or printed by retailers when needed.

Will the Transfer Between Sectors Be Allowed?

Alternative 1: Transfer between commercial and recreational sectors is allowed

Alternative 2: No trading between sectors

The basic economic notions of efficiency suggest that unfettered trading between the recreational and commercial sectors should be allowed. However the transfer of TRs between commercial sector and recreational sector can be controversial. While unconstrained transfer of the rights between sectors would increase short-run net benefits to market participants, it can have some negative consequences.

First, regional depletion could occur if the purchasing sector is geographically concentrated. Second, there is the potential for market concentration, particularly if rights are grandfathered and assigned in perpetuity as is done in most ITQ programs. The third reason for such a restriction would be concerns about secondary impacts on related economic participants. If the recreational sector purchased some of commercial rights, this could affect not only the fishermen, but the processing and marketing sectors as well. Similar impacts on the tourism industry would occur if the trades went the other direction. While in a full-employment economy such concerns have little economic merit, in situations of localized unemployment and/or situations with species-specific capital investments, such secondary impacts should not be ignored. The fourth reason, which is probably the most common real reason for such restrictions, is political pressure to protect the rights of one resource user group over those of another group. Such pressures are likely to come with particular force from secondary market participants who have nothing to gain when rights are sold.

There is certainly a precedent for such restrictions. In the Alaska Halibut program, charter boat operators can purchase IFQ shares from the commercial fishery, but shares originally allocated to the charter sector (recreational sector) cannot be sold to the commercial sector (Sutinen et al. 2002).

How Should Monitoring and Enforcement Be Carried Out?

One of the central challenges of TR programs is monitoring and enforcement. This issue is more salient in the case of TRs than in most other markets. When physical commodities are considered, if someone wants to obtain something they have little choice but to find a seller. In the case of TRs, however, someone who wants to use a public resource may do so unless someone is monitoring their behavior to ensure that they have purchase the right. In the end, the government, as the caretaker of those resources, must take final responsibility for ensuring that the public resource is used only by those that have obtained a use right.

Closures and gear restrictions are relatively easy to enforce. By contrast, particularly in a multiple-species deep-see fishery such as the GRS, it would be difficult to ensure that all anglers fishing for red snapper have the necessary right. Sutinen and Johnston (2003) point out that the more disaggregated the rights are distributed, the more difficult monitoring becomes. In particular, they argue that the monitoring problem gives AMOs a distinct advantage since the unit needed to be monitored would be much greater. Although the AMO approach could offer some advantages in this regard, in the end it is the individual anglers that harvest the fish. Hence, regardless of whether the right is transferred directly to the angler, or the angler receives the right indirectly through an AMO or a local government agency, at some point individual behavior must be monitored.

The system of allocation can affect monitoring in that if funds are collected, for example through an auction of the initial allocation, this would generate revenue that would be available for monitoring and the amount of money available would be proportional to the value of the rights. If the rights command a high price, then more money would be available for monitoring. On the other hand, if the price of the rights is low, then little revenue would be available but the incentive to fish without a permit would also be low.[10]

Should Size and Bag Limits Be Retained?

As we noted above, size and bag limits can be very inefficient devices for the control of total harvests. On the other hand, there are legitimate reasons for maintaining these restrictions based on biological factors and concerns for equity. If rights are defined in terms of pounds or fish, then these rights should probably take the place of bag limits. If rights are defined as a day of use, then restrictions on that use would almost certainly be required in the form of bag limits. In the Alaskan Halibut program, in which rights are defined in terms of fish landed, a bag limit is retained. However, it should be recognized that bag limits provide incentives for discards and if discard mortality is significant then these limits can be counterproductive. In this case, therefore, bag limits should be set only to ensure a degree of equitability, but should not be used as a means to reducing total catch.

As discussed above, size limits can be particularly problematic when used as a means to control harvest. Regardless of the units in which the TR is established, therefore, we believe that size limits should be set only to address biological concerns relating to recruitment, and should not be used as a means to reduce total catch.

[10] Note, that some level of monitoring is necessary to avoid an equilibrium in which the price is low because everyone is cheating.

A Proposal for a Recreational TR Program in the Gulf of Mexico Red Snapper Fishery

We now briefly propose a system for TRs in the GRS fishery that we believe is implementable and would lead to substantial improvements in the management of that recreational fishery. We believe that recreational fisheries can be well suited for TR management system. Our proposal is for a system of Red Snapper TR (RSTR) and it would have the following characteristics:

- RSTR would be day-based rights that must be terminated before beginning a fishing day. The rights would be a record on an electronically maintained registry.
- Rights would be held by individual anglers.
- RSTR would be not expired and would be valid to fish anywhere in the Gulf of Mexico.
- The initial allocation would be carried out through all schemes. For private-rental boat users, multiple auctions or lotteries during the year could be used. A larger number of auctions might be necessary in the first years of the program, but after several years it may be possible to sell all rights in one or two auctions. In case of head boat sector which keeps recording historical harvests, grandfathering could be used. In case of charter sector, rights could be initially allocated to AMOs and then they will distribute rights to charter boat operators.
- Since rights are electronic, monitoring of all trades would be critical.
- Trades would take place in retail markets, through e-markets or a government established clearing house.

- No restrictions on speculation would be imposed so that the market will decide the clearing price of TRs.
- At least initially, we propose that limited transfer between commercial and recreational sectors
- Monitoring and enforcement should be carried out with high penalties for anglers fishing without a valid day right.
- Since we propose that rights be denominated as a day fished, bag limits would need to be retained, but they could be increased because they are no longer the principal tool used for control of total harvests. Size limits should be used to address biological concerns regarding recruitment, but they should not be used as a device to reduce harvests.

All these preferred and desired options could enable the newly created TR market to work properly and successfully. It is, however, believed that the proposed market for TR in recreational fishery can be treated as a real market and end up being close to a market for private goods.

Concluding Remarks

In contrast to commercial fisheries which have been the center of ITQ studies, little attention has been paid to the implementation of TRs in the recreational fishery. This Chapter provides the background necessary to begin exploring in more detail the issues of how a TR program might be implemented in the red-snapper recreational fishery. In the chapter we have briefly summarized the issues at stake and present the advantages and disadvantages of alternative solutions. These practical issues for ITQ programs in the recreational sector were studied based on the literature and case studies of successfully implemented TR programs, particularly in other areas (e.g., pollution credit markets and commercial ITQ systems).

Although the use of TRs in recreational fisheries is a relatively new idea, we believe that it is an idea that has a great deal of merit and the institutional barriers are not insurmountable. In the rest of this dissertation we will take this idea one step further, studying the potential for such a program using theoretical and empirical models.

CHAPTER III

THEORETICAL MODEL OF TRANSFERABLE RIGHTS IN RECREATIONAL FISHERY

One of the questions in chapter II was how transferable rights should be measured. As indicated, the possible alternatives are: the number of fish landed, the number of days spent fishing, and total weight (e.g., pounds) of fish landed. In this chapter, analytical models of three different measurement unit alternatives of TRs are developed and comparative statics of decision variables is done with respect to the permit price.

Transferable Rights Under Different Unit of Measurement

In contrast to commercial fisheries ITQs, which profit maximization is the objective, TR programs for the recreational sector must be evaluated in terms of a representative angler's utility maximization problem. Following Woodward and Griffin (2003), who adapted the standard practice in the recreation demand literature, we assume that an angler's utility is a function of the number of "*days*" spent fishing (equivalent in trips), d, a composite good representing other goods purchased, x_0, the number of fish retained or "*landed*," l, the average "*size*" of the retained fish, s, and the "*time*" per day spent fishing, t. This model is not dynamic but static for a utility maximization problem similar to a household production model.

Because their utility function includes the subfunction, q, the angler's utility function can be weakly separable and his or her decision of taking a fishing trip can be treated as a two-stage decision. After the angler chooses how many days (d) to be taken during the year and his other expenditures over the course of the year, then the angler must choose some other variables such as time per day spent fishing (t), the number of fish landed (l), size of fish (s), which define the quality of a given fishing trip for each day.

However, unlike in Woodward and Griffin, the weakly separable assumption can not be applied in the TRs permit system because the angler must buy the TRs permits which are directly related to d and l, before he or she decides to go fishing. For example, if the rights are issued in fish, the angler should choose d and l, at the same time. Consequently, the framework used here drops the quality subfunction and assumes that an angler's utility is affected directly by the variables d, l, s and t.

In addition, the angler faces the marginal cost per day, c, and has a fixed income of m that is spent in paying for trip expenditures and other goods. Woodward and Griffin (2003) pointed out due to a fixed cost per day, the model is directly applicable only to cases where the angler is considering one site, or cases in which all alternative sites are indistinguishable in terms of both cost and quality.

All variables are assumed to positively affect the angler's utility and concavity condition for each decision variable is also assumed. Anderson (1993) pays attention to the tradeoffs between *l* and *d* and Homans and Ruliffson (1999) concentrate on tradeoffs between *l* and *s*. We follow these tradeoff relationships for *l*-*d* and *l*-*s*. In the absence of regulations, the representative angler's decision problem is to choose *d*, *t*, *l*, *s*, and x_0 to maximize *U* subject to a budget constraint and a physical limit constraint that landings cannot exceed the number of fish harvested. The specification in the absence of regulations is as follows:

$$\begin{aligned} &\max U\left(d, l, s, t, x_0\right) \text{ s.t.} \\ &\quad c \times d + x_0 \leq m \\ &\quad l \leq h\left(t; X\right), \end{aligned}$$

where *h* is the catch per day, which is a function of the time spent fishing on that day, *t*, and the fish stock, *X*.

From the first-order condition of the above equation with respect to x_0, it follows that at the optimum, U_{x_0} equals the shadow price on the budget constraint. Dividing $U(\cdot)$ by U_x, we obtain a money-metric function, $u\left(d, l, s, t\right)$, which indicates the total willingness to pay for *d* day trips (Woodward and Griffin, 2003). The angler's optimization problem, therefore, can be as follows:

$$\begin{aligned} &\max u\left(d, l, s, t\right) + u_0 x_0 \text{ s.t.} \\ &\quad c \cdot d + x_0 \leq m \\ &\quad l \leq h\left(t; X\right) \\ &\quad s \leq f(l, h). \end{aligned}$$

Again, x_0 is the composite good and u_0 is its price which is usually set to one. The size constraint $s \leq f(l,h)$ indicates the feasible combinations of *l* and *s* given that the angler has spent t hours in fishing and harvested $h(t;X)$ fish. The function f will show opposite direction in l and $h(.)$, meaning that if harvests or landings increase (decrease), size of fish will decrease (increase). An angler confronts the tradeoffs between the number of fish landed and the size of the catch (Woodward and Griffin 2003). Technology used in fishing such as nets and lines is not precisely included in the model but we assume that the trip cost (c) incorporates some of the fishing technology: expensive equipment will increase c. We also assume that c contains the opportunity cost of time, so that higher income people will have a greater cost.

Three alternatives can be considered for the measurement units of TR program as we introduce them in the previous chapter: i) rights in *fish*, TR_f , ii) rights in *days* spent fishing, TR_d , and iii) rights in *pounds* or weights, TR_p . These TRs measurement units would provide different utility maximization solutions.

Transferable Rights in Terms of Fish

The rights could be stated in terms of the number of fish and a TRs holder of such a right would be allowed to harvest one fish (presumably of legal size) per permit. Fish-based TRs are consistent with existing regulations such as bag limits. However, if TRs are denominated in terms of numbers, there would be an incentive to discard smaller, less valuable fish.

If the unit of measurement for TRs is based on the number of fish, the quantity of TRs permits (TR_f) purchased by each individual should be no less than the number of days spent fishing d times the amount of fish landed l. We call this condition ($l \cdot d \le TR_f$) as the TRs limit constraint. In the budget constraint, the cost of purchasing TRs permits ($P_f \cdot TR_f$) should be added, where P_f is the price of a TRs permit. A representative angler's problem is as follows:

$$\begin{aligned}
&\max u(d,l,s,t) + u_0 x_0 \\
\text{s.t. } & P_f \cdot TR_f + c \cdot d + x_0 \le m \\
& l \le h(t;X) \\
& s \le f(l,h) \\
& l \cdot d \le TR_f .
\end{aligned}$$

Define constraints as:

$$\begin{aligned}
&P_f \cdot TR_f + c \cdot d + x_0 \le m && \text{: Budget Constraint.} \\
&l \le h(t;X) && \text{: Landing Constriant.} \\
&s \le f(l,h) && \text{: Size Constraint.} \\
&l \cdot d \le TR_f && \text{: TRs Limit Constraint.}
\end{aligned}$$

The fishing pattern which maximizes the angler's utility given constraints can be determined by the above model. There are five decision variables in this model: the number of days spent fishing d, the number of fish landed l, the average size of the retained fish s, the time spent fishing t, and the amount of TRs permit purchased TR_f. If anglers are rational, all constraints should be binding except for the size constraint $s \le f(l,h)$, because anglers are likely to choose bigger size fish rather than more fish landed. However we check the Lagrangian of this model is as follows:

$$\begin{aligned}
L = {} & u(d,l,s,t) + u_0 x_0 - \lambda(P_f \cdot TR_f + c \cdot d + x_0 - m) - \mu(l - h(t;x)) \\
& - \phi(s - f(l,h)) - \delta(d \cdot l - TR_f).
\end{aligned}$$

From the first order condition with respect to x_0, it indicates that at the optimum u_0 equals the shadow price on the budget constraint λ. Without loss of generality, suppose the budget constraint is binding and the nonnegative u_0 equals 1. Hence we can drop out the shadow price of the budget constraint λ.

$$L = u(d,l,s,t) - (P_f \cdot TR_f + c \cdot d - m) - \mu(l - h(t;X)) - \phi(s - f(l,h)) - \delta(d \cdot l - TR_f).$$

The necessary conditions for an interior solution with respect to the decision variables d, r, l, s, t are respectively as follows:

$$\frac{\partial L}{\partial d} = \frac{\partial u(\cdot)}{\partial d} - c - \delta \cdot l = 0 \qquad [3.1]$$

$$\frac{\partial L}{\partial TR_f} = -P_f + \delta = 0 \qquad [3.2]$$

$$\frac{\partial L}{\partial l} = \frac{\partial u}{\partial l} - \mu - \delta \cdot d + \phi \cdot f_l^{'} = 0 \qquad [3.3]$$

$$\frac{\partial L}{\partial s} = \frac{\partial u}{\partial s} - \phi = 0 \qquad [3.4]$$

$$\frac{\partial L}{\partial t} = \frac{\partial u}{\partial t} + \mu \cdot \frac{\partial h}{\partial t} + \phi \frac{\partial f}{\partial h}\frac{\partial h}{\partial t} = 0. \qquad [3.5]$$

Note that $\partial u/\partial d = u_d^{'}$, $\partial u/\partial l = u_l^{'}$, $\partial u/\partial s = u_s^{'}$, and $\partial u/\partial t = u_t^{'}$. $\partial f/\partial h = f_h^{'}$, and $\partial h/\partial t = h_t^{'}$. From equation [3.2] which directly implies that δ should equal the permit price P_f, if P_f is not equal to zero, δ should be nonnegative. That is, anglers will purchase additional TR permits until the willingness to pay for additional permit is equal to the trip cost.

$$\frac{\partial L}{\partial \delta} = -d \cdot l + TR_f = 0. \qquad [3.6]$$

Using [3.1] and [3.2], the optimal number of fish landed can be readily found to be:

$$l^* = \frac{u_d^{'} - c}{P_f}. \qquad [3.7]$$

From [3.3] and [3.2], the optimal number of days spent fishing becomes:

$$d^* = \frac{u_l^{'} - \mu + \phi \cdot f_l^{'}}{P_f} = \frac{h_t^{'}(u_l^{'} + u_s^{'} \cdot f_l^{'}) + (u_t^{'} + u_s^{'} \cdot f_t^{'})}{h_t^{'} \cdot P_f}. \qquad [3.8]$$

After substituting [3.7] and [3.8] into [3.6] and arranging it, then the optimal number of TRs permits purchased for each angler becomes:

$$TR_f^{\ *} = \frac{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}{P_f^{\ 2}} = \frac{(u_d^{'} - c) \cdot (h_t^{'}(u_l^{'} + u_s^{'} \cdot f_l^{'}) + (u_t^{'} + u_s^{'} \cdot f_t^{'}))}{h_t^{'} \cdot P_f^{\ 2}}. \qquad [3.9]$$

Shadow prices could be eliminated using $\phi = u_s^{'}$ and $\mu = -(u_t^{'} - u_s^{'} \cdot f_t^{'}) / h_t^{'}$ in [3.8] and [3.9]. If $\mu = -(u_t^{'} - u_s^{'} \cdot f_t^{'}) / h_t^{'}$ is greater than zero, differentiating L with respect to μ yields $l = h(t; X)$. The optimal solution for the time of spending fishing can be written:

$$t^* = h^{-1}(l^*; X), \qquad [3.10]$$

where $h^{-1}(\cdot)$ is the inverse function of the harvesting function $h(\cdot)$. Because ϕ is also nonnegative, the optimal size can be simply written by taking derivative L with respect to ϕ:

$$s^* = f(l^*, h(t^*; X)). \qquad [3.11]$$

The optima are dependent on marginal utilities of all the decision variables and derivatives of the harvest function and the size function. Because we do not know functional forms of utility, size and harvest functions, as an empirical matter, one will rarely be able to test relations of variables directly and find economic implications from the solutions. However, if our interest is in the direction of change, we can use comparative statics for the marginal changes of decision variables responding to the change in exogenous variables.

Because price is an important role for market transactions under the TR program it is important to analyze the effect of change in the price on the decision variables such as *l*, *d*, and TR. Comparative statics of the change in TRs permit price is the following:

$$\frac{\partial l^*}{\partial P_f} = -\frac{(u_d^{'} - c)}{P_f^{\ 2}} = -\frac{l^*}{P_f} < 0 \qquad [3.12]$$

$$\frac{\partial d^*}{\partial P_f} = -\frac{(u_l^{'} - \mu + \phi \cdot f_l^{'})}{P_f^{\ 2}} = -\frac{d^*}{P_f} < 0 \qquad [3.13]$$

$$\frac{\partial TR_f^{\ *}}{\partial P_f} = -\frac{2 \cdot d^* \cdot l^*}{P_f} < 0. \qquad [3.14]$$

Because all numerators for above equations are positive, all derivatives with respective to the permit price should be negative. It implies that a policy of increasing the permit price leads to decrease the number of days fished, and the number of fish landed. The law of demand for the TRs permit is satisfied from [3.14], indicating that if the permit price goes up the number of permits an angler would purchase will decrease.

Conversely, a policy of reduction in the total number of TRs would increase the permit price. Differentiating t^* with respect to p will yield

$$\frac{\partial t^*}{\partial P_f} = \underset{+}{\frac{\partial h^{-1}}{\partial l}} \underset{-}{\frac{\partial l}{\partial P_f}} < 0. \quad [3.15]$$

Note that without loss of generality, the *inverse* harvest function is increasing in the number of fish landed ($\partial h^{-1} / \partial l > 0$). If the price goes up, anglers will spend less time fishing. Taking derivative of s with respect to P_f can be written

$$\frac{\partial s^*}{\partial P_f} = \underset{-}{\frac{\partial f}{\partial l}} \underset{-}{\frac{\partial l}{\partial P_f}} + \underset{-}{\frac{\partial f}{\partial h}} \underset{+}{\frac{\partial h}{\partial t}} \underset{-}{\frac{\partial t}{\partial P_f}} > 0. \quad [3.16]$$

Note that $\partial f / \partial l < 0$ and $\partial f / \partial h < 0$, indicating that the size function *f*(·) is decreasing in the number of fish landed or harvested because of the tradeoff between s and *l* (or *h*(·)). It is also obvious that if harvest function *h*(·) is increasing in the time spent fishing then $\partial h / \partial t > 0$. Following equation [3.16], if the price of TRs which are stated in *fish* goes up, anglers are likely to catch bigger size fish.

To sum up, if the price of the fish-based TRs increases, decision variables will show:

- the number of TRs purchased will decrease,
- the number of fish landed will decrease,
- the time spent fishing will decrease,
- the number of fishing trips will decrease, and
- the size of fish caught will increase.

Transferable Rights in Terms of Days

TRs could alternatively be stated in terms of the number of days for fishing as opposed to quantity-based rights. If stated as the number of days, bag limits would probably be used to control total catch. Relative to the other alternatives, a day-based permit is more easily monitored and enforced, but introduces more uncertainty in the number of fish caught and the size of caught fish.

If the unit of TRs is in days, the number of TR permit purchased by each individual, TR_d, should be no less than the number of days spent fishing d ($d \le TR_d$). Other constraints are the same as the case of rights in fish above. A representative angler's utility maximization problem if the unit of transferable rights is in days is as follows:

$$\begin{aligned} &\max u\left(d,l,s,t\right) + u_0 x_0 \\ &\text{s.t. } P_d \cdot TR_d + c \cdot d + x_0 \le m \\ &\qquad l \le h\left(t;X\right) \\ &\qquad s \le f(l,h) \\ &\qquad d \le TR_d . \end{aligned}$$

The Lagrangian of this model is as follows:

$$L = u(d,l,s,t) - (P_d \cdot TR_d + c \cdot d - m) - \mu(l - h(t;X)) - \delta(d - TR_d) - \phi(s - f(l,h)).$$

The necessary conditions for an interior solution with respect to the decision variables $d, TR_d, l, s,$ and t are as follows:

$$\frac{\partial L}{\partial d} = \frac{\partial u\left(\cdot\right)}{\partial d} - c - \delta = 0 \qquad [3.17]$$

$$\frac{\partial L}{\partial TR_d} = -P_d + \delta = 0 \qquad [3.18]$$

$$\frac{\partial L}{\partial l} = \frac{\partial u}{\partial l} - \mu + \phi \frac{\partial f}{\partial l} = 0 \qquad [3.19]$$

$$\frac{\partial L}{\partial s} = \frac{\partial u}{\partial s} - \phi = 0 \qquad [3.20]$$

$$\frac{\partial L}{\partial t} = \frac{\partial u}{\partial t} + \mu \cdot \frac{\partial h}{\partial t} + \phi \cdot \frac{\partial f}{\partial h}\frac{\partial h}{\partial t} = 0. \qquad [3.21]$$

If the permit price is greater than zero, the marginal value of an extra TR permit, δ, should be nonnegative. This condition provides a fixed constraint of the number of days, *d*, as follows:

$$\frac{\partial L}{\partial \delta} = -d + TR_d = 0. \qquad [3.22]$$

The number of permits purchased, TR_d, equals the number of days d. In contrast to TRs in fish, we can not observe the optimal solutions of these decision variables. However, some comparative statics could be derived using second derivatives.

After differentiating [3.17], $u_d^{'} - c = P_d$, with respect to P_d, and then $\partial d / \partial P_d$ could be derived as follows:

$$\begin{aligned} &\frac{\partial^2 u}{\partial d^2}\frac{\partial d}{\partial P_d} + \frac{\partial^2 u}{\partial d \partial l}\frac{\partial l}{\partial P_d} = \frac{\partial P_d}{\partial P_d} \\ &\frac{\partial d}{\partial P_d} = \left(1 - \frac{\partial^2 u}{\partial d \partial l}\frac{\partial l}{\partial P_d}\right)\left(\frac{\partial^2 u}{\partial d^2}\right)^{-1}. \end{aligned} \qquad [3.23]$$

If the cross-partial effect is relatively small, then, due to the concavity of utility function, the derivative of the number of days fishing with respect to the permit price is less than zero.

$$\frac{\partial d}{\partial P_d} < 0 \text{ and } \frac{\partial TR_d}{\partial P_d} < 0. \quad [3.24]$$

As the permit price goes up, an angler will decrease the number of fishing trips. Because $TR_d = d$, the condition will also say that the TR permit demand follows negatively sloped curve with respect to its price. The law of demand is confirmed under day-based TRs.

After differentiating [3.19], $u_l^{'} - \mu + \phi \cdot f_l^{'} = 0$, with respect to P_d, and then $\partial l / \partial P_d$ could be derived as follows:

$$\frac{\partial^2 u}{\partial l^2}\frac{\partial l}{\partial P_d} + \frac{\partial^2 u}{\partial l \partial d}\frac{\partial d}{\partial P_d} - \frac{\partial \mu}{\partial P_d} - \frac{\partial \phi}{\partial P_d} f_l - \phi \frac{\partial^2 f}{\partial l^2}\frac{\partial l}{\partial P_d} = 0$$

$$\left(\frac{\partial^2 u}{\partial l^2} - \phi \frac{\partial^2 f}{\partial l^2}\right)\frac{\partial l}{\partial P_d} = -\frac{\partial^2 u}{\partial l \partial d}\frac{\partial d}{\partial P_d} + \frac{\partial \mu}{\partial P_d} + \frac{\partial \phi}{\partial P_d} f_l \quad [3.25]$$

$$\frac{\partial l}{\partial P_d} = \left(\underbrace{-\underbrace{\frac{\partial^2 u}{\partial l \partial d}}_{A}\underbrace{\frac{\partial d}{\partial P_d}}_{-}}_{A} + \underbrace{\frac{\partial \mu}{\partial P_d}}_{0} + \underbrace{\frac{\partial \phi}{\partial P_d}}_{0} \underbrace{f_l}_{?} \right)\left(\underbrace{\frac{\partial^2 u}{\partial l^2}}_{-} \underbrace{-\phi}_{+} \underbrace{\frac{\partial^2 f}{\partial l^2}}_{?0} \right)^{-1}.$$

Assuming $\partial^2 f / \partial l^2$ is small, the derivative of the number of fish landed with respect to the permit price will have a sign of $-\partial^2 u / \partial l \partial d$. If $\partial^2 u / \partial l \partial d$ is less than zero,[11]

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[11] It is hard to prove the sign of cross derivative $\partial^2 u / \partial l \partial d$ but it may be very small and likely be less than zero.

then the comparative statics of l with respect to P_d is greater than zero ($\partial l/\partial P_d > 0$). In this case, the number of fish landed will increase as the price of the day-based TRs increases. No matter how much fish anglers catch within the bag limit, they will pay the same amount of money under the day-based TR program. Anglers may catch more fish to get some compensation as the price increases. This is the reason the bag limit would probably be maintained when TRs are denominated by days.

In equation [3.19] and [3.20], we can confirm that shadow prices could be nonnegative using $\phi = u_s^{'}$ and $\mu = -(u_t^{'} - u_s^{'} \cdot f_t^{'})/h_t^{'}$. Differentiating L with respect to ϕ and μ yields $l = h(t;X)$ and $s = f(l,h(\cdot))$, respectively. The time spent fishing, t, can simply be the inverse harvest function of l ($t = h^{-1}(l;X)$). We can not obtain the optimal solutions of t and s, either. It does not mean that day-based permit is inferior to the other quantity-based rights because failing to derive the optimal solutions is a mathematical problem. However, some comparative statics could be derived as follows:

$$\frac{\partial t}{\partial P_d} = \underset{+}{\frac{\partial h^{-1}}{\partial l}} \underset{+}{\frac{\partial l}{\partial P_d}} > 0 \qquad [3.26]$$

$$\frac{\partial s}{\partial P_d} = \underset{-}{\frac{\partial f}{\partial l}} \underset{+}{\frac{\partial l}{\partial P_d}} + \underset{-}{\frac{\partial f}{\partial h}} \underset{+}{\frac{\partial h}{\partial t}} \underset{+}{\frac{\partial t}{\partial P_d}} < 0. \qquad [3.27]$$

Note that if the number of fish landed is increasing in the permit price anglers will spend more time fishing. As shown in equation [3.27], if the price of TRs which are stated in *day* goes up, anglers are likely to catch smaller fish ($\partial s/\partial P_d < 0$).

To sum up, if the price of the day-based TRs increases:

- the number of TRs purchased will decrease,
- the number of fish landed will increase,
- the time spent fishing will increase,
- the number of fishing trips will decrease, and
- the size of caught fish will decrease.

Transferable Rights in Terms of Pounds

TRs could be stated in terms of the pounds. If stated as pounds, the total number of TRs permits should be set to be equal to the recreational sector's portion of the TAC – e.g., 4.47 million lbs. The advantage of this approach is that it would be most directly comparable with the TAC and would reduce the incentive to discard undersize fish.

If the unit of TRs is in pounds, the amount of TR permit purchased TR_p should be no less than a coefficient of average pound $\alpha(s)$ times $l \cdot d$ ($\alpha \cdot s \cdot l \cdot d \leq TR_p$). For simplicity here we assume the relationship between the pounds and the size of fish is linear ($\alpha(s) = \alpha \cdot s$). Other constraints are the same as the other cases of fish-based and day-based TRs. A representative angler's utility maximization problem if the unit of TRs is in pounds is as follows:

$$\begin{aligned} &\max u\left(d, l, s, t\right) + u_0 x_0 \\ \text{s.t. } &P_p \cdot TR_p + c \cdot d + x_0 \leq m \\ &l \leq h\left(t; X\right) \\ &s \leq f(l, h) \\ &\alpha \cdot s \cdot l \cdot d \leq TR_p. \end{aligned}$$

The Lagrangian of this model is as follows:

$$L = u(d,l,s,t) - (P_p \cdot TR_p + c \cdot d - m) - \mu(l - h(t;X)) - \phi(s - f(l,h)) - \delta(\alpha \cdot s \cdot d \cdot l - TR_p).$$

The first order necessary conditions for an interior solution with respect to the decision variables $d, TR_p, l, s,$ and t are as follows:

$$\frac{\partial L}{\partial d} = \frac{\partial u}{\partial d} - c - \delta \cdot \alpha \cdot s \cdot l = 0 \qquad [3.28]$$

$$\frac{\partial L}{\partial TR_p} = -P_p + \delta = 0 \qquad [3.29]$$

$$\frac{\partial L}{\partial l} = \frac{\partial u}{\partial l} - \mu - \delta \cdot \alpha \cdot s \cdot d + \phi \frac{\partial f}{\partial l} = 0 \qquad [3.30]$$

$$\frac{\partial L}{\partial s} = \frac{\partial u}{\partial s} - \delta \cdot \alpha \cdot d \cdot l - \phi = 0 \qquad [3.31]$$

$$\frac{\partial L}{\partial t} = \frac{\partial u}{\partial t} + \mu \cdot \frac{\partial h}{\partial t} + \phi \frac{\partial f}{\partial h} \frac{\partial h}{\partial t} = 0. \qquad [3.32]$$

Unless the price becomes zero, the shadow price of the TR limit constraint δ should again be nonzero. Then

$$\frac{\partial L}{\partial \delta} = -\alpha \cdot s \cdot d \cdot l + TR_p = 0. \qquad [3.33]$$

From [3.28] and [3.29], the amount of fish landed becomes:

$$l = \frac{u_d^{'} - c}{P_d \cdot \alpha \cdot s}. \qquad [3.34]$$

Arranging [3.29] and [3.30] yield the number of days spent fishing:

$$d = \frac{u_l^{'} - \mu + \phi \cdot f_l^{'}}{P_d \cdot \alpha \cdot s}. \qquad [3.35]$$

After substituting equation [3.34] and [3.35] into [3.31] and rearranging, the optimal size can be measured:

$$P_d \cdot \alpha \cdot \left(\frac{u_d^{'} - c}{P_d \cdot \alpha \cdot s} \right) \left(\frac{u_l^{'} - \mu + \phi \cdot f_l^{'}}{P_d \cdot \alpha \cdot s} \right) = u_s^{'} - \phi$$

$$s^2 = \frac{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}{P_p \cdot \alpha \cdot (u_s^{'} - \phi)}$$

$$s^* = \sqrt{\frac{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}{P_p \cdot \alpha \cdot (u_s^{'} - \phi)}}. \qquad [3.36]$$

Substituting equation [3.36] into [3.34] and [3.35], the optimal *l* and *d* are obtained:

$$l^* = \sqrt{\frac{(u_d^{'} - c) \cdot (u_s^{'} - \phi)}{P_p \cdot \alpha \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}} \qquad [3.37]$$

$$d^* = \sqrt{\frac{(u_l^{'} - \mu + \phi \cdot f_l^{'}) \cdot (u_s^{'} - \phi)}{P_p \cdot \alpha \cdot (u_d^{'} - c)}}. \qquad [3.38]$$

Substituting equation [3.36], [3.37] and [3.38] into [3.33], we can get the optimal number of TRs purchased.

$$TR_p^* = \sqrt{\frac{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'}) \cdot (u_s^{'} - \phi)}{P_p^{\ 3} \cdot \alpha}} \qquad [3.39]$$

The effects of the change in TRs permit price on the decision variables are as follow:

$$\frac{\partial s^*}{\partial P_p} = -\frac{\sqrt{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}}{2 \cdot P_p^{\frac{3}{2}} \cdot \sqrt{\alpha \cdot (u_s^{'} - \phi)}} < 0 \qquad [3.40]$$

$$\frac{\partial l^*}{\partial P_p} = -\frac{\sqrt{(u_d^{'} - c) \cdot (u_s^{'} - \phi)}}{2 \cdot P_p^{\frac{3}{2}} \cdot \sqrt{\alpha \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'})}} < 0 \qquad [3.41]$$

$$\frac{\partial d^*}{\partial P_p} = -\frac{\sqrt{(u_l^{'} - \mu + \phi \cdot f_l^{'}) \cdot (u_s^{'} - \phi)}}{2 \cdot P_p^{\frac{3}{2}} \sqrt{\alpha \cdot (u_d^{'} - c)}} < 0 \qquad [3.42]$$

$$\frac{\partial TR_p^{\;*}}{\partial P_p} = -\frac{2\sqrt{(u_d^{'} - c) \cdot (u_l^{'} - \mu + \phi \cdot f_l^{'}) \cdot (u_s^{'} - \phi)}}{3 \cdot P_p^{\frac{5}{2}} \cdot \sqrt{\alpha}} < 0. \qquad [3.43]$$

Because all numerators and denominators for above equations are positive, all derivatives with respective to the permit price should be negative. It implies that if the permit price issued in pounds increases, decision variables such as *s*, *d*, *l* would decrease. The law of demand for the TRs permit is also satisfied from [3.43], indicating that if the permit price goes up, the number of permits an angler would purchase will decrease.

Because the shadow prices of the landing constraint μ could be nonzero, differentiating L with respect to μ yields $l = h(t; X)$. The optimal solution for the time spent fishing t can be the inverse harvest function of l ($t^* = h^{-1}(l^*; X)$). Taking derivative of t^* with respect P_p will be expressed:

$$\frac{\partial t^*}{\partial P_p} = \underset{+}{\frac{\partial h^{-1}}{\partial l}} \underset{-}{\frac{\partial l}{\partial P_p}} < 0. \qquad [3.44]$$

The time an angler spends in fishing will increase as the price goes up.

To sum up, if the price of the pound-based TRs increases:

- the number of TRs purchased will decrease,
- the number of fish landed will decrease,
- the time spent fishing will decrease,
- the number of fishing trips will decrease, and

- the size of fish caught will decrease.

Comparison between Unit Alternatives

In the analysis of previous section the angler seeks to maximize his or her utility subject to some constraints including the TRs limit constraint. In order to address which TRs unit of measurement is preferred, we use the tradeoffs between *d* and *l* which appear in the TRs limit constraints.

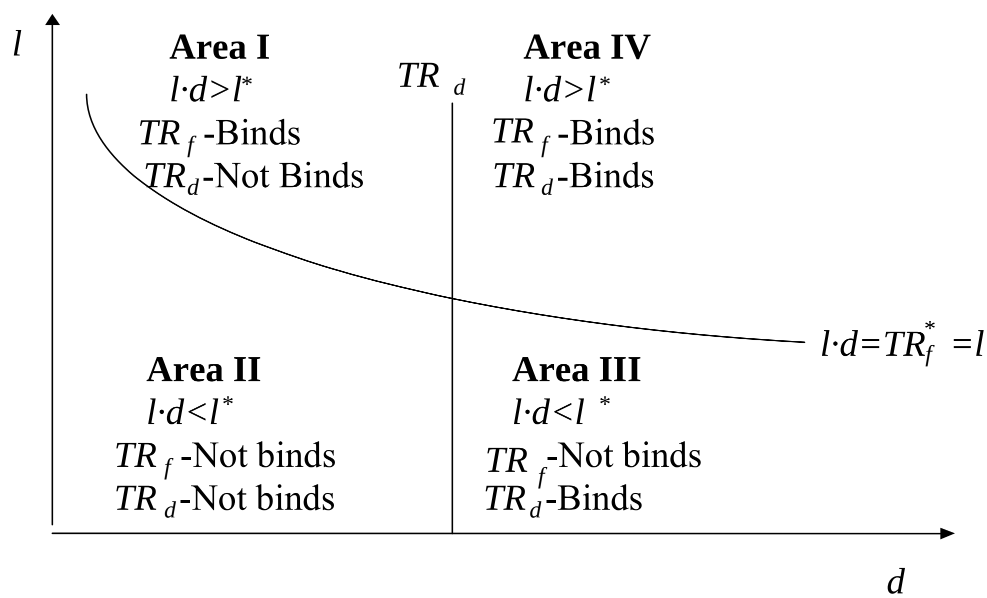

FIGURE 3.1

Comparison between Day and Fish Based TRs

Figure 3.1 shows *l*-*d* space of two TRs limit constraints between TRs in fish and days. For given $h(t)$, an angler will choose a point in this space. Negatively sloped line with asymptotic tails $l \cdot d = TR_f$ indicates the TRs limit constraint in fish and is assumed to equal a certain level of the number of fish landed l^*. The vertical line $d = TR_d$ indicates the TRs limit constraint in days.

These constraints between *l* and *d* segment four areas. Area 1 implies the region of *l*-*d* combination where the TRs limit constraint in days does not bind ($d < TR_d$) but the TRs limit constraint in fish binds ($l \cdot d = TR_f$). Area 2 indicates the region where both constraints do not bind ($d < TR_d$ and $l \cdot d < TR_f$). Area 3 reflects the region where the TRs constraint in fish does not bind ($l \cdot d < TR_f$) but the TRs limit constraint in days binds ($d = TR_d$).Finally, area 4 presents the region where both TRs limit constraints bind ($d = TR_d$ and $l \cdot d = TR_f$).

The optimal solutions of *l* and *d* on area 2 and 4 might not tell which unit of TRs permit would be preferred. If area 1 and 3 are chosen, the preferred unit of measurement for TRs will be controversial. If the optimal solution of the number of days spent fishing and the amount of fish landed is located on area 1, the TRs permit in fish will be preferred. On the other hand, if the optimal solution is determined on area 3, the day-based TRs permit will be preferred to the fish-based TRs.

If TRs are stated as the number of days, bag limits would be used to control total catches. Figure 3.2 shows TRs limit constraints and bag limit on *l*-*d* space. If the bag limit which is classified by the horizontal line l^b is implemented for TRs in days, areas above l^b such as area 1, 4 and the shaded area 5 can not be chosen. In this case, an angler's choice combination between *d* and *l* is highly restricted in area 3 and anglers are likely to prefer the day-based permit to fish-based permit.

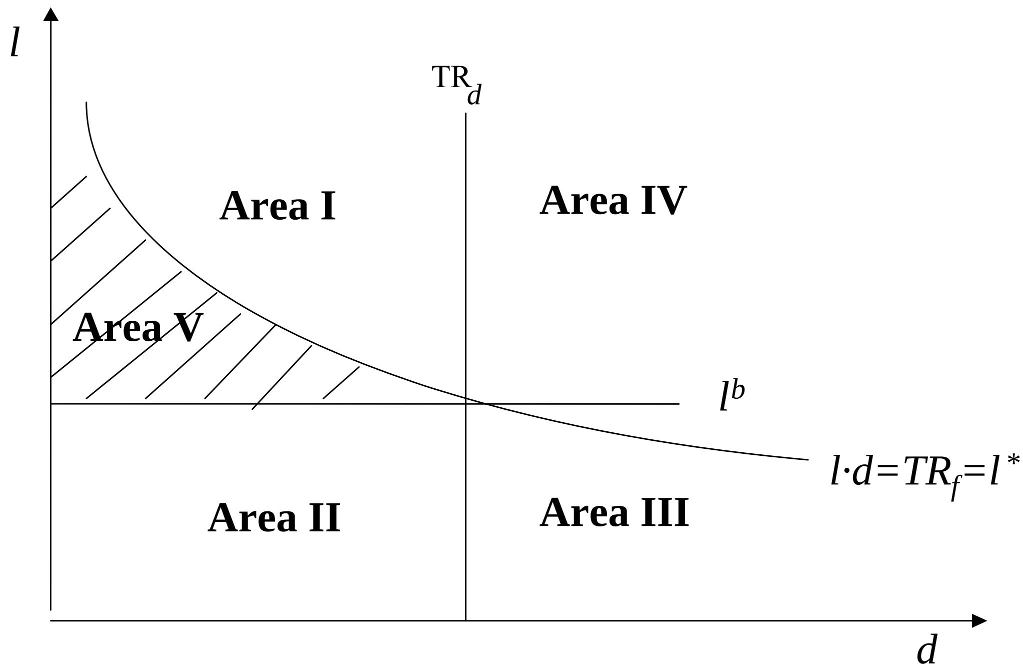

FIGURE 3.2

Comparison between Day and Fish Based TRs in the Presence of Bag Limits

Comparison between TRs Units Using Specified Functional Forms

We can explore the relative advantages of the different units of measurement for TRs in more detail by making assumptions about the functional form of the angler's utility function. Assuming a quadratic utility function in each decision variable, a representative angler's utility function is as follows:

$$\begin{aligned} u &= (\gamma_d + \alpha_d d + \beta_d d^2) + (\gamma_l + \alpha_l l + \beta_l l^2) + (\gamma_s + \alpha_s s + \beta_s s^2) + (\gamma_t + \alpha_t t + \beta_t t^2) \\ &= \gamma + (\alpha_d d + \beta_d d^2) + (\alpha_l l + \beta_l l^2) + (\alpha_s s + \beta_s s^2) + (\alpha_t t + \beta_t t^2), \end{aligned}$$

where $\gamma = \gamma_d + \gamma_l + \gamma_s + \gamma_t$.

The β s are negative and the α s are positive, which implies that the utility function is weakly concave in the variables. In addition, the harvest function $h(t;X)$ and the size function $f(l,h)$ are assumed as follows:

$$h(t;X) = k \cdot t,$$

$$f(l,h) = \overline{s}(1 - \frac{l}{h}) + \underline{s} \cdot \frac{l}{h},$$

where k is the catch rate per time (e.g., one fish an hour), $\overline{s}$ is the highest size and $\underline{s}$ indicates the lowest size an angler can catch. The assumption that the landing constraint is binding, meaning that $l = h = k \cdot t$ and $s = \underline{s}$, is imposed because of difficulty to solve inequality constraints. If the quantity of fish landed equals the quantity of fish harvested, an angler should catch the lowest size fish because there is a negative relationship between size and the amount of fish landed. If this strong assumption is imposed, the inequality constraints are replaced by equality constraints.

We stress the comparison between unit of TRs in fish and unit of TRs in days because the unit in pounds is just TRs in fish times the average pound per fish which is a function of size.

Unit in Fish

The utility maximization problem using the quadratic utility function is now as follows.

$$\max u = \gamma + (\alpha_d d + \beta_d d^2) + (\alpha_l l + \beta_l l^2) + (\alpha_s s + \beta_s s^2) + (\alpha_t t + \beta_t t^2)$$
$$\text{s.t.} \quad P_f \cdot TR_f + c \cdot d = m$$
$$l = k \cdot t$$
$$l \cdot d = TR_f$$
$$s = \underline{s}.$$

The Lagrangian we would solve if the unit is stated in fish is as follows:

$$L = \gamma + (\alpha_d d + \beta_d d^2) + (\alpha_l (k \cdot t) + \beta_l (k \cdot t)^2) + (\alpha_s \underline{s} + \beta_s \underline{s}^2) + (\alpha_t t + \beta_t t^2)$$
$$- (P_f \cdot d \cdot (k \cdot t) + c \cdot d - m).$$

Decision variables are $d, l, s, t,$ and TR_f, and parameters are P_f and c . New coefficients of the specified functions include $(\alpha_d, \alpha_l, \alpha_s, \alpha_t)$ and $(\beta_d, \beta_l, \beta_s, \beta_t)$ for the utility function and k for the harvest function. The signs of α s are positive and the signs of β s are negative for concavity of the quadratic utility function. All other parameters $P_f, k, c, m,$ and $\underline{s}$ are positive.

The first order necessary conditions for an interior solution with respect to the decision variables d and t are as follows:

$$\frac{\partial L}{\partial d} = \alpha_d + 2\beta_d \cdot d - P_f \cdot k \cdot t - c = 0 \qquad [3.45]$$

$$\frac{\partial L}{\partial t} = \alpha_l \cdot k + 2\beta_l \cdot k^2 \cdot t + \alpha_t + 2\beta_t \cdot t - P_f \cdot d \cdot k = 0 \qquad [3.46]$$

$$d = \frac{c - \alpha_d + P_f \cdot k \cdot t}{2\beta_d}. \qquad [3.47]$$

Substitute [3.47] into [3.46], and arrange it.

$$\alpha_l \cdot k + \alpha_t + 2\beta_l \cdot k^2 \cdot t + 2\beta_t \cdot t - P_f \cdot k(\frac{c - \alpha_d + P_f \cdot k \cdot t}{2\beta_d}) = 0$$

$$2\beta_d(\alpha_l \cdot k + \alpha_t) + 2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) \cdot t - P_f \cdot k(c - \alpha_d) - P_f^2 \cdot k^2 \cdot t = 0$$

$$(2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2) \cdot t = P_f \cdot k(c - \alpha_d) - 2\beta_d(\alpha_l \cdot k + \alpha_t).$$

The optimal t under fish-based TRs is written

$$t_f^* = \frac{P_f \cdot k(c - \alpha_d) - 2\beta_d(\alpha_l \cdot k + \alpha_t)}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}. \qquad [3.48]$$

The subscript f indicates the fish permits. Similarly, the optimum d becomes:

$$d = \frac{1}{2\beta_d}\left[(c - \alpha_d) + P_f \cdot k \cdot \left\{\frac{P_f \cdot k(c - \alpha_d) - 2\beta_d(\alpha_l \cdot k + \alpha_t)}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}\right\}\right]$$

$$d = \frac{1}{2\beta_d}\left[\frac{(c - \alpha_d)\left\{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - p_f^2 \cdot k^2\right\} + P_f \cdot k \cdot \left\{P_f \cdot k(c - \alpha_d) - 2\beta_d(\alpha_l \cdot k + \alpha_t)\right\}}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}\right]$$

$$d = \frac{1}{\cancel{2\beta_d}}\left[\frac{(c - \alpha_d) \cdot \cancel{2\beta_d}(2\beta_l \cdot k^2 + 2\beta_t) \cancel{-(c - \alpha_d) \cdot P_f^2 \cdot k^2} \cancel{+P_f^2 \cdot k^2(c - \alpha_d)} - P_f \cdot k \cdot \cancel{2\beta_d}(\alpha_l \cdot k + \alpha_t)}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}\right]$$

$$d_f^* = \frac{(c - \alpha_d)(2\beta_l \cdot k^2 + 2\beta_t) - P_f \cdot k \cdot (\alpha_l \cdot k + \alpha_t)}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}. \qquad [3.49]$$

The optimal l_f is as follows in [3.50]:

$$l_f^* = \frac{P_f \cdot k^2(c - \alpha_d) - 2\beta_d \cdot k \cdot (\alpha_l \cdot k + \alpha_t)}{2\beta_d(2\beta_l \cdot k^2 + 2\beta_t) - P_f^2 \cdot k^2}. \qquad [3.50]$$

Now, we get the optimal solutions for fish-based TRs. These solutions will be used for comparison with day-based TRs.

Unit in Days

The utility maximization problem using the quadratic utility function is now as follows:

$$
\begin{aligned}
&\max u = \gamma + (\alpha_d d + \beta_d d^2) + (\alpha_l l + \beta_l l^2) + (\alpha_s s + \beta_s s^2) + (\alpha_t t + \beta_t t^2)\\
&\text{s.t. } P_d \cdot TR_d + c \cdot d = m\\
&\quad l = k \cdot t\\
&\quad d = TR_d\\
&\quad s = \underline{s}.
\end{aligned}
$$

The Lagrangian we would solve is as follows:

$$
\begin{aligned}
L = {} & \gamma + (\alpha_d d + \beta_d d^2) + (\alpha_l (k \cdot t) + \beta_l (k \cdot t)^2) + (\alpha_s \underline{s} + \beta_s \underline{s}^2) + (\alpha_t t + \beta_t t^2)\\
& - (P_d \cdot d + c \cdot d - m).
\end{aligned}
$$

The first order necessary conditions for an interior solution with respect to the decision variables d, t are as follows:

$$\frac{\partial L}{\partial d} = \alpha_d + 2\beta_d \cdot d - P_d - c = 0 \qquad [3.51]$$

$$\frac{\partial L}{\partial t} = \alpha_l \cdot k + 2\beta_l \cdot k^2 \cdot t + \alpha_t + 2\beta_t \cdot t = 0. \qquad [3.52]$$

From equation [3.51], the optimal d becomes:

$$d_d^* = \frac{(c - \alpha_d) + P_d}{2\beta_d}. \qquad [3.53]$$

Using equation [3.52], the optimal t can be written:

$$t_d^* = \frac{-(\alpha_l \cdot k + \alpha_t)}{2\beta_l \cdot k^2 + 2\beta_t}. \qquad [3.54]$$

The subscript d indicates the day-based permits. Finally, the optimal l under the day-based TRs becomes:

$$l_d^* = \frac{-k(\alpha_l \cdot k + \alpha_t)}{2\beta_l \cdot k^2 + 2\beta_t}. \quad [3.55]$$

Using these optimal solutions of decision variables for fish-based and day-based TRs, now we can analyze which unit of measurement for TRs is preferable.

Comparison between Two Unit Alternatives

Let the symbols D_d, D_l, and D_t be the differences of optimal *d*, *l*, and *t* between unit alternatives. The signs of differences between l_f^* and l_d^*, and between t_f^* and t_d^* are demonstrated in [3.56] and [3.57]. Positive sign indicates the optimal level of the number of fish for the fish-based TRs are greater than that for day-based TRs and vice verse (see Appendix 1 for specific calculation). Using the assumptions stated above, we find

$$D_l = l_f^* - l_d^* < 0 \text{, and} \quad [3.56]$$

$$D_t = t_f^* - t_d^* < 0. \quad [3.57]$$

Because D_l is negative, TRs denominated in days provide more fish landed than do TRs denominated in fish. Similarly, TRs denominated in days allow anglers to spend more time than do TRs denominated in fish. The sign of difference between d_f^* and d_d^* is shown at [3.58]. Positive sign indicates the optimal solution of fishing days for fish-based TRs is greater than that for day-based TRs, and vice verse.

$$D_d = d_f^* - d_d^* > 0. \quad [3.58]$$

Fish-based TRs provide anglers with more days spent fishing than do day-based TRs. After substituting all decision variables into the utility function, we can compare which unit of measurement is preferred in terms of utility (see appendix 1).

$$D_U = u_f - u_d < 0 \text{ or} > 0 . \qquad [3.59]$$

We can not assure which unit alternative gives greater utility to an angler. If anglers put more weight on the number of fish landed or fishing time when they evaluate their utilities of fishing, the utility under day-based TRs will be greater than that under fish-based TRs ($u_f < u_d$). On the other hand, if they want more days for fishing, fish-base TRs will be preferred to the day-based TRs.

The results using defined signs of coefficients indicate that a day-based permit provides more fish landed and more fishing time than does a fish-based permit. On the other hand, fish-based permit allows anglers to spend more days in fishing than does the day-based permit. It is ambiguous which unit of measurement for TRs provides fishermen with bigger utility.

Fish-based permit for the recreational TRs supplies some advantages. First, it gives more fishing days to anglers. Under current fishing regulations, open days for fishing are strictly limited so that anglers can not go fishing as much as they want to fish. TR program under fish-based permit will increase their fishing days and they may go fishing as much as or whenever they want. Anglers who have a small number of permits can utilize all remaining permits at once on the last day that their permits are valid.

A day-based permit has also some advantages. First, it can be more easily monitored and enforced. Fishing authorities will be able to easily confirm and check how many permits anglers use when they leave or come back so that rights constraint which states that the number of permits they use should not exceed the number of rights permits they purchase can be satisfied. Second, anglers can catch and land more fish per trip. If they place more weights on the number of fish landed in their utility, the day-based permit may be preferred.

Concluding Remarks

This chapter provides a theoretical model to investigate the effects of the change in the TR permit price on the key decision variables such as the number of fish landed, the number of days taking fishing trips, the size of caught fish, and the time spent fishing. We set up different models by the unit of measurement such as fish-based, day-based, and pound-based TRs. The law of demand is satisfied for TR program no matter what unit of measurement is used.

In addition, we analyze which unit of measurement is preferable between fish-based and day-based TRs. Under the assumptions made here, some of which are quite strong, the fish-based permit allows anglers to spend more days fishing and the day-based permit gives greater fish landed and fishing time. An angler's preference between fish-based and day-based permits in terms of utility depends on coefficients' magnitudes in his or her utility function.

CHAPTER IV

ON THE USE OF DISCRETE CHOICE MODEL FOR RECREATION DEMAND ANALYSIS

The objective of this chapter is to empirically estimate recreation demand that incorporates TR permit demand. Because the model uses travel cost as an approximate variable of the price, it is often called Travel Cost model (TCM). We expect that when TR program is implemented the price (cost) of fishing will increase because anglers are required to buy TR permits additionally to go fishing. Our focus is on estimating an effect of price changes on the fishing trip demand.

Suppose the price of taking a fishing trip increases simply by paying a daily access fee. A daily fee will be directly compatible with day-based TRs discussed in the previous two chapters. The difference is that a fee is fixed by the government, but the price of day-based TRs can vary by market demand. In this chapter we examine a daily access fee policy as an approximate price instrument of TR program. We find that a fee can be very effective in reducing recreational fishing demand in the Gulf of Mexico. Income is an important determinant of an individual's choice to travel to go fishing and, if an individual chooses to fish, which fishing mode is chosen.

Background

A price instrument such as fees and TR programs might be a way to reduce recreational effort that would avoid the inefficiencies that arise because of season closures. In particular, relative to alternative ways to control congestion or over-use, fees have the advantage of leading to a more economically efficient outcome because they make it possible for those that value the resource most highly to use it. However, of most relevance here, fees are criticized on the grounds of equity since they tend to exclude the poorest user groups from use of resources (More and Stevens 2000). Any implementation of fees (increase in price) in recreation management inevitably raises the issue of equity although fees are touted for the numerous advantages in terms of economic efficiency. Important questions to policy makers are: Is it unfair to low income people to charge substantial fishing fees? Do recreational fees disproportionately impact anglers who engage in the least expensive mode of fishing? Should we worry if secondary impacts on merchants and service providers are distributed inequitably?

Economic analysis of recreational behavior should provide results that capture distributional consequences so that these questions might be answered. Revealed preference models of recreation demand are often estimated using discrete choice approaches falling into the class of random utility models, and unfortunately, within these, the marginal utility of income is typically assumed to be constant [e.g., Caulkins et al.(1986) and Bockstael et al.(1987)]. In contrast, in our model below, the sensitivity to price varies across fishing modes (access by charter boat, private boat, from shore) and income, allowing estimation of the distributional impacts that a fee might have across user groups. The estimated recreational demand is mode-specific to analyze which mode users are more affected by price changes.

Literature Review

To begin, we first briefly consider the random utility model (RUM) and the role that income plays in such models. Second we review some literature on imposing fees in the recreational setting. The use of the RUM in recreation demand or travel cost models is now quite well documented in the literature. We cannot provide an extensive review of such literature here, and that has been done in numerous other papers (see for example, the introductory chapter in Hanley et al. and references therein). The RUM has a few distinct advantages over some other types of models (specifically the single-site count data approach) in that it handles substitution among sites rather well. However, in virtually all existing recreation demand models that have been estimated using the RUM-based approach, income effects are assumed to be absent. We are aware of very few estimated RUM models that appear in published or unpublished papers that allow for a non-constant marginal utility of income.[12] Doing so generally leads to some very difficult technical issues (for discussion see Herriges and Kling 1999; McFadden 1999; Shaw and Ozog 1999).

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[12] Shonkwiler and Shaw (2003) consider the impact of a $5 increase in the fee at one of the Columbia River main-stem reservoirs within a finite mixture model that allows for income effects, but this is quite different than the usual RUM model. They find that recreational users in one regime experience almost twice the loss in consumer's surplus as those in another income regime.

Distributional consequences of environmental or resource programs have been considered in a variety of settings, including tradable pollution permits, the share of water shortages, and in situations where “grandfathering” allocation schemes are allowed (see Ruström and Williams 2005). The distributional impacts of recreation fees, in the context of well-developed recreation demand models, have not been frequently addressed in the mainstream literature on travel cost modeling. One notable exception is the contingent valuation study by Adams et al. (1989): their study of hunting and fees illustrates that lower income groups have higher losses than higher income hunters when a flat “per-head’ fee is imposed.

Several authors of leisure studies (Reiling et al., 1996; Bowker et. Al, 1999; More and Stevens, 2000) have concluded that implementation of a fee or an increase in a fee would lower recreational participation by low-income people. More and Stevens (2000) found that a $5 daily fee to access public lands would affect almost half of the low-income people as compared to a smaller portion (33%) of high-income people. Reiling et al. (1996) estimated that recreational demand for public lands on the part of low-income groups is more elastic than that of middle or high income groups, which implies that low income people would be more responsive to a price increase. These studies support the notion that income inequity is problematic in recreational activities. In contrast to these studies, Kyle et al. (2002) find no significant correlation between household income and willingness to pay for fees, and Winter et al. (1999) found that income was less helpful in understanding public response to fees than a measure of social trust.

Our econometric model below draws on recent work by Morey et al. (2003a and 2003b) that incorporates income effects in a simple fashion. Morey and his colleagues assume that utility is “a piece-wise linear spline function” of expenditures. In this case, the change in the marginal utility of money is assumed to be a step function of money income. This piece-wise spline approach is used to deal with income effect below. The approach is well suited for our income data set, which is available categorically. We use this approach within the context of a repeated discrete choice random utility model.

Model

To estimate recreational demand, one would ideally like to know the destination, the frequency, and what mode is chosen for each trip. Such data is rarely available, for the simple reasons that collecting it is complicated, there are limits to respondent recall, and such data are cost-prohibitive. Hence, it is often the case that data are gathered as in the MRFSS data used in this study, with rather complete information about a single intercept trip and less complete data for other trips that the individual may have taken. Although the data are not as complete as the analyst might desire, the partial data on the non-intercept trips do offer potentially valuable insights into angler preferences and their demand for fishing trips. Morey, Shaw, and Rowe (hereafter MRS-1991) developed a statistical and theoretical model that takes advantage of data of this type, and we follow very closely the discrete choice-random utility model they developed.

Random Utility Model of Fishing Participation and Mode Choice

In the MSR model, the assumption was made that anglers engage in a pattern corresponding to a repeated decision, leading to a "repeated" discrete choice or random utility model of recreation demand. The repeated choice model framework is adopted by Morey et al. (1993), and Shaw and Ozog (1999), and a host of others. Issues and extensive discussion can be found in Morey (1999) and Parsons et al. (1999). Using this model in our context, an angler confronts two simultaneous decisions: whether to go recreational fishing at all, and if the angler does so, the mode that will be used, i.e. whether to fish from shore, from a private boat, from a rental boat, or from a charter boat. Kim, Shaw, and Woodward (forthcoming) estimate a model with county specific destinations. Here our emphasis is on tradeoffs across modes, so we treat the Gulf of Mexico as a uniform destination, but the distance that an angler has to travel to reach the Gulf varies widely.

The econometric model essentially reduces to estimating two conditional probabilities. First, an angler *i* has a daily probability of not going fishing equal to π_i^{nf}. In the given fishing period, *X*, she takes Q_i trips, not including the trip where we observe the angler's destination. Over the *X* days in a period there are $\left[X!/\left(Q!\left(X-Q\right)!\right)\right]$ combinations of *Q* days so that the probability of observing Q_i trips becomes

$$f_1(Q_i)=\left[\frac{X!}{Q_i!(X-Q_i)!}\right](\pi_i^{nf})^{(X-Q_i)}(1-\pi_i^{nf})^{Q_i}. \qquad [4.1]$$

Second, we estimate the probability, π_{mi}^{f}, that an angler *i* chooses mode *m* for her intercept trip. Defining y_{mti} =1 if an angler *i* took mode *m* on the trip where we observe the angler's mode in period *t* and y_{mti} =0 otherwise, the marginal distribution of choosing mode *m* can be concisely written

$$f_2(y_{mti}) = \prod_{s=1}^{M} (\pi_{si}^{f})^{y_{sti}} . \qquad [4.2]$$

Finally, following MSR (1991), we combine these two conditional probabilities to form the likelihood function. Given a random sample of *N* independent participants and assuming that Q_i and y_{mti} are independently distributed, the probability of observing the participation and mode choices for the anglers in the sample is

$$L = \prod_{i=1}^{N} f(Q_i, y_{mti}) = \prod_{i=1}^{N} f_1(Q_i)\, f_2(y_{mti}), \qquad [4.3]$$

where $f(Q_i, y_{mti})$ is the joint distribution.

The use of the probability in equation [4.3] in the likelihood function would suffer from intercept bias since those that fish more often are more likely to be interviewed. Hence, in the likelihood function estimated, we introduce a correction for potential intercept bias, replacing the distribution of unobserved trips with a sampling distribution that assumes being in the sample is proportional to the total number of trips one takes.[13] With this assumption, the modified likelihood function becomes:

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[13] See the intercept bias correction discussed in MSR (1991), their equation 14, and the relevant text where results are discussed.

$$L=\prod_{i=1}^{N}\left\{\frac{Q_i+1}{[(1-\pi_i^{nf})X+1]}\right\}\left\{\left(\frac{X!}{Q_i!(X-Q_i)!}\right)\left(\pi_i^{nf}\right)^{X-Q_i}\left(1-\pi_i^{nf}\right)^{Q_i}\right\}\left\{\prod_{m=1}^{M}\left(\pi_{mi}^{f}\right)^{y_{mi}}\right\}. \quad [4.4]$$

In order to estimate the probabilities of making the mode and participation choices, a functional form for the indirect utility function must be specified. Applying the typical linear specification of a RUM model to the problem of mode choice, the utility of an angler in period t is a function of the angler's fishing budget in period t, B_{ti}, and whether or not a particular mode m has been chosen at a personal cost of P_{mi}. In addition to the price and budget, catch rate (CR_m) will affect utility when the angler takes a trip. That is, we write $U_{0ti}=\alpha_0+\beta\left(B_{ti}\right)$ if the angler does not fish, and $U_{mti}=\alpha_m+\gamma\cdot CR_m+\beta\left(B_{ti}-P_{mi}\right)+\varepsilon_{mti}$ if the angler chooses mode m, where ε_{mti} is the error terms capturing unexplained variation in the utility when the angler chooses to fish. The coefficients α_0 and α_j can be functions of variables describing the angler, the mode, or the season.

An angler will not fish if the reservation utility, U_{0ti}, is greater than the utility enjoyed in all of the modes. Hence the probability that an angler does not fish, π_i^{nf}, is the probability that $U_{0ti}>U_{mti}$ for all other modes, so π_i^{nf} is a decreasing function of the difference $U_{mti}-U_{0ti}$. This difference can be simplified to

$$U_{mti}-U_{0ti}=\left(\alpha_m-\alpha_0\right)+\gamma\cdot CR_m-\beta P_{mi}+\varepsilon_{mti}\,. \quad [4.5]$$

As in MSR (1991) it is assumed that the non-fishing utility is deterministic so that the error in this equation is captured in the single error term, ε_{mti}. There is a straight forward interpretation of equation [4.5]. The difference between the α's in the parentheses can be thought of as the utility gain achieved by fishing using mode *m*. The $-\beta P_{mi}$ term reflects the cost in terms of decreased utility that the angler must pay in order to gain the benefits of the fishing trip. The usual assumption in the applied literature is that the marginal utility of income is constant so that β is the same for all possible uses of income or income levels. This specification implies, therefore, that if an angler's fishing costs increase by one dollar, his or her utility declines by a fixed amount that does not vary across incomes or for any other reason. We believe that it is intuitively plausible that β's may actually vary across both modes and incomes. For example, the angler's response to a one dollar increase in the cost of a charter fishing trip, with an average cost of over $250, may be quite different from his or her response to a one dollar increase in the cost of a $30 shore fishing trip. If the marginal effect of a price change varies across modes, then we would rewrite [4.5] as

$$U_{mti} - U_{0ti} = \left(\alpha_m - \alpha_0\right) + \gamma \cdot CR_m - \beta_m P_{mi} + \varepsilon_{mti}, \qquad [4.6]$$

allowing for a separate coefficient β_m for each of the *m* categories. Regardless of whether [4.5]] or [4.6] is used, only the coefficient on the price is identified; the coefficient on income can only be identified to the extent that it is assumed to be equal to the coefficients on the prices.

The specification suggested by [4.5] is a restricted form of [4.6], a theoretical restriction that can be tested empirically. In our empirical application, we allow the β parameters to vary across modes, after testing and rejecting this restriction. Rejection of this hypothesis does not necessarily mean that consumers are violating a fundamental principle of consumer behavior, but it does suggest that anglers' demand behavior is more complicated than is typically assumed.

In equation [4.6], it is assumed that the marginal utility of money varies depending on the type of mode being chosen. Alternatively or in addition, it might be that the β parameters vary across income groups. To allow for this type of variation, we adopt Morey et al.'s (2003a, 2003b) linear spline function approach in which the marginal utility of income varies for different income brackets. If this approach is adopted, then an angler's utility (temporarily suppressing the coefficient on and the catch rate variable) taking a trip in mode *m* would be written

$$\begin{aligned} U_{mti} &= \alpha_0 + \beta_0 \left(B_{ti} - P_{mi} \right) + \varepsilon_{mti} && \text{if } (B_{ti} - P_{mi}) \leq M_0 \\ &= \alpha_0 + \beta_0 M_0 + \beta_1 \left(B_{ti} - M_0 - P_{mi} \right) + \varepsilon_{mti} && \text{if } M_0 < (B_{ti} - P_{mi}) \leq M_1 \\ &= \alpha_0 + \beta_0 M_0 + \beta_1 \left(M_1 \right) + \beta_2 \left(B_{ti} - M_1 - P_{mi} \right) + \varepsilon_{mti} && \text{if } M_1 < (B_{ti} - P_{mi}), \end{aligned} \quad [4.7]$$

where M_0 and M_1 are threshold points where it is assumed that the marginal utility of income changes. If this approach is used, then the utility difference equation, [4.5], would be rewritten

$$U_{mti} - U_{0ti} = \left(\alpha_m - \alpha_0 \right) + \gamma \cdot CR_m - \beta_j P_{mi} + \varepsilon_{mti} \quad [4.8]$$

where j=0,1,2 for the three different income categories. Again, the specification in [4.5] is a testable restriction of [4.8].

Finally, equation [4.9] is the most flexible specification, in which the slope coefficients vary across both income and mode. In this case, [4.5] would be written

$$U_{mti} - U_{0ti} = \left(\alpha_m - \alpha_0 \right) + \gamma \cdot CR_m - \beta_{jm} P_{mi} + \varepsilon_{mti} \quad [4.9]$$

where the marginal utility of money, β_{jm}, is allowed to vary for each combination of mode and income.

Regardless of the utility specification chosen, as shown in Morey (1999) if we assume that in each period the angler's vector is randomly drawn from a Type I Extreme Value distribution then the joint CDF of this distribution is

$$F_{\varepsilon}(\varepsilon_{ti}) = \exp\left[\sum_{m=1}^{M} -\exp(-\varepsilon_{mti})\right]. \qquad [4.10]$$

Letting V_{0ti} and V_{mti} indicate the deterministic part of the angler's utility (i.e. without ε_{0ti} and ε_{mti}, respectively), we obtain the specifications that are actually used in estimation as in Morey et al. (1991). The probability of not fishing becomes

$$\pi_i^{nf} = \text{Prob }[U_{0ti} > U_{mti}, \forall m] = \exp\left\{-\sum_{m=1}^{M} \exp\left[-(V_{0ti} - V_{mti})\right]\right\}. \qquad [4.11]$$

Once the decision to go fishing has been made, the probability of choosing mode m over the other modes can be written

$$\pi_{mi}^{f} = \text{Prob }[U_{mti} > U_{sti}, \forall s] = 1 \Big/ \sum_{s=1}^{M} \exp\left[-(V_{mti} - V_{sti})\right]. \qquad [4.12]$$

After selecting the model to be estimated, [4.5], [4.6], [4.8], or [4.9], equations [4.11] and [4.12] are used in the likelihood function to find the parameters of each model.

Data, Estimation, and Empirical Results

Data

The data used here come from the 1997 Marine Recreational Fishery Statistics Survey (MRFSS). The history of the MRFSS data set is discussed in Hicks et al. (1999) and the data used here are from the 1997 study (discussed in detail in Whitehead and Haab, 1999), using the economic add-on to the standard intercept data. The approach to collecting the data is commonly used by the National Marine Fisheries Service and the data here are almost identical in nature to the data originally encountered by MSR (1991). In these data, there is complete information only about the intercept trip, and partial information about other trips that the angler takes in a two-month period. Anglers in 1997 MRFSS intercept survey were contacted at a variety of locations including docks, marinas, and other sites along the Gulf Coasts (except Texas coast). The follow-up economic survey was conducted over the telephone. The data are divided into six waves of two months each.

The questions in the survey include those about general characteristics of respondents, their number of fishing days within last two months, specific information of intercept trips, *i*.e., what mode of fishing they engaged in, when they went fishing, and what they targeted and caught. Here we focus on single-day trips at four states along the Gulf of Mexico coast. The sampling was stratified by mode (table 4.1). Anglers that were interviewed fished an average of 7.11 days during the two month fishing period and they have an average of 18.1 years of fishing experience.

The most common mode of fishing for anglers in our sample was using a private boat (73%), which is not surprising since about 63% of anglers own a boat. The other modes are by charter boat (4.1%), with the remainder fishing from the shore (22.9%). Interviews were spread unevenly throughout the year with a greater proportion conduced in the Sep-Oct and May-Jun waves (19.8%) and the fewest in the coldest and hottest months, Jan-Feb and Jul-Aug (12.8% and 14.2%, respectively).

TABLE 4.1

Distributions and Variable Summary Statistics

		Frequency	Percentage
Mode Distribution			
Charter		153	4.1%
Private		2696	73.0%
Shore		845	22.9%
Fishing Period Distribution			
Jan-Feb	($Dwave_1$)	474	12.8%
Mar-Apr	($Dwave_2$)	579	15.7%
May-Jun	($Dwave_3$)	733	19.8%
Jul-Aug	($Dwave_4$)	525	14.2%
Sep-Oct	($Dwave_5$)	733	19.8%
Nov-Dec		650	17.6%
Income Distribution			
less than $35,000	(DM_0)	1768	47.9%
$35,001 to $75,000	(DM_1)	1559	42.2%
Greater than $75,001	(DM_2)	367	9.9%
Other Dummy			
Own a boat	(*Dboat*)	2314	62.6%
Target red snapper	(*Dredsn*)	42	1.1%
		Mean	Std. Dev
Trips		7.11	8.47
Experience	(*Exper*)	18.06	14.16

Note: Variable names in parentheses where appropriate.

The survey questionnaire identified income in 11 categories, which we aggregate into three broad categories: low (less than $35,000), middle ($35,001 to $75,000), and high (greater than $75,001). These income levels correspond roughly to the 50% and 80% thresholds for U.S. households reported in the U.S. Census Bureau's Current Population Survey.[14] Because 34% of respondents in the sample do not reveal their income, the log linear ordinary least squares regression model suggested and estimated by Haab et al. (2000) is used to impute missing income values. After using imputed income, those in the low income category constitute 47.9% of the total sample. The middle income category contains 42.2% of the respondents, and the rest of the sample (9.9%) falls into the high income category.

Travel costs to the three modes for 38 destinations near the angler's home (the intercept destinations) are constructed using distances calculated using the Zipfip program. In addition, the opportunity cost of an angler's time in travel to and from the site is factored in using assumed travel speeds and reported wage rates as the opportunity cost of time per hour, if these are available in the anglers' responses. For anglers not reporting wage rates but reporting annual income we used average hourly income instead, and for those reporting neither wage nor income, we used a hedonic regression to predict their wage rate per hour (see Appendix 2). Retirees are assumed to have an opportunity cost of time equal to the minimum wage rate. Because we construct only a mode choice model, the travel costs and opportunity costs of time to get to the intercept

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[14] In 1997, 50% of the U.S. households had an income less than $40,699, 80% less than $78,638 (http://www.census.gov/hhes/income/histinc/ie4.html).

destinations do not vary across modes but vary widely by anglers. Other expenses and boat fees varying by mode are computed simply as the sample average. It is noteworthy that the average cost of fishing from a charter vessel is considerably more than all other modes, and sometimes an order of magnitude more costly than the cost of shore fishing. The averages of the predicted prices for charter, private, and shore fishing are shown in table 4.2.

TABLE 4.2

Average Predicted Prices across Modes of Fishing

Means	Charter	Private	Shore
Travel Cost and Opportunity Cost of Time	22.8	22.8	22.8
Other Expenditure	17.5	29.6	7.2
Boat Fee	222.5	-	-
Total Price	262.8	52.4	30.0

The mode-site catch rates are the average of reported catch rates for each site and mode. When, for a given mode-site combination, only a few anglers report catch, the average reported catch could be problematic. As our sample is rather large, this was not a major problem, but when less than 20 observations were available, observations from adjacent site(s) were included until at least 20 observations were obtained. In this way, a catch rate was available for each of the all sites and for each of the three modes. The averages of catch rates for charter, private, and shore fishing are 3.53, 2.71, and 1.71, respectively.

Estimation

The parameters of the model are estimated by maximizing the log likelihood function:

$$\begin{aligned}\ln L &= \ln(Q_i+1) - \ln[(1-\pi_i^{nf})X+1] - \ln[Q_i!(X-Q_i)!] + \ln(X!) \\ &\quad - \ln[Q_i!(X-Q_i)!] + (X-Q_i)\ln(\pi_i^{nf}) + Q_i \ln(1-\pi_i^{nf}) + \sum_{m=1}^{M} y_{mi} \ln(\pi_{mi}^{f})\end{aligned} \quad [4.13]$$

We assume that the decision whether to fish or not is a function of the season as captured by an intercept term and the season as picked up by dummy variables for the five waves: $Dwave_1$ =1 if the respondent is surveyed in Jan-Feb,…, $Dwave_5$=1 if the respondent is intercepted in Sep-Oct. The probability of not fishing or staying at home is also a function of a dummy variable of targeting red snapper, *Dredsn*, boat ownership, *Dboat*=1 if yes, and the angler's experience in years, *Exper*. In addition to an intercept term for each mode, α_{0m}, mode choice is also assumed to be a function of $CatchRate_m$. Income levels are identified in the dummy variables DM_0=1 if household income is less than \$35,000, DM_1=1 if household income is \$35,000 to \$75,000, and DM_2=1 if household income is greater than \$75,001.[15] Using the most general specification with separate slope coefficients for each mode and income category, the final empirical specification of the probability of not fishing and mode choice from equations [4.11] and [4.12] can be written as

$$\pi_i^{nf} = \exp\left\{ -\sum_{m=1}^{M} \exp\left[\begin{array}{l} -\left(\sum_{j=1}^{5} \alpha_j Dwave_j\right) - \alpha_7 Dredsn - \alpha_8 Exper - \alpha_9 Dboat \\ +\alpha_{0m} + \gamma CR_m - \left(\beta_{0m} DM_0 + \beta_{1m} DM_1 + \beta_{2m} DM_2\right) P_{mi} \end{array} \right] \right\} \quad [4.14]$$

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[15] Note that the dummy variable trap is avoided because there no default coefficient.

and

$$\pi_{mi}^{f} = 1 \bigg/ \sum_{s=1}^{M} \exp\begin{bmatrix} \alpha_{0s} - \alpha_{0m} + \gamma(CatchRate_s - CatchRate_m) \\ -(\beta_{0s}DM_0 + \beta_{1s}DM_1 + \beta_{2s}DM_2)P_{si} \\ +(\beta_{0m}DM_0 + \beta_{1m}DM_1 + \beta_{2m}DM_2)P_{mi} \end{bmatrix}. \qquad [4.15]$$

Note that the intercept term, α_{0m}, captures the difference between intercept in the non-fishing and mode-*m* utility function, i.e. $\alpha_{0m} = \alpha_m - \alpha_0$ in [4.5], [4.6], [4.8] or [4.9]. With π_i^{nf} and π_{mi}^{f} defined by [4.14] and [4.15], the parameters of the unrestricted model are found by maximizing [4.4] with respect to the parameters. Equivalently, the restricted models, [4.5], [4.6], and [4.8], are estimated by making the suitable restrictions in the equations for V_{0ti} and V_{mti}.

Estimation Results

Estimation results for participation and mode choice model are presented in Table 4.3.[16] The alternative models associated with different specifications of the price coefficient are presented. We estimated four different models corresponding to equations [4.5], [4.6], [4.8] and [4.9], models 1 through 4. Only one price coefficient is used in model 1, mode-specific price coefficients are used in model 2, income specific coefficients are estimated in model 3, and both mode and income specific price coefficients are estimated in model 4. Our focus is here on testing the slope coefficients in the utility difference equations vary across both mode and income. Based on the

[16] The standard errors that yield the t statistics in Table 4.3 are computed from analytic second derivatives (Newton) supplied by the econometrics program TSP.

likelihood ratio test, we reject at the 1% level all restrictions on the model. That is, we reject the hypothesis that the price coefficient is constant across modes, [4.5]=[4.6], that it is constant across income levels, i.e., [4.5]=[4.8], or both of these restrictions simultaneously, [4.5]=[4.9]. Following our model specification tests, we focus the remainder of our discussion on the preferred and most general model, Model 4, in which the price coefficient is allowed to vary for each mode and income group.

TABLE 4.3

Estimation Results of Participation-Mode Choice Model

Parameter	Model 1 One Price coefficient Estimate	Model 2 Mode-specific Price coefficients Estimate	Model 3 Income Specific Price coefficients Estimate	Model 4 Mode and Income specific Price coefficients Estimate
α_{0Ch}	3.3865	1.6558	3.4031	2.9852
(Constant)	(28.62)	(23.73)	(26.01)	(23.60)
α_{0Pr}	3.9828	4.7467	3.9821	4.0196
(Constant)	(94.60)	(54.05)	(93.12)	(51.07)
α_{0Sh}	2.6163	3.2589	2.6127	3.3132
(Constant)	(67.55)	(58.40)	(62.04)	(55.17)
γ	0.0473	0.0856	0.0467	0.0886
(CatchRate)	(4.86)	(13.78)	(4.72)	(14.44)
β_{0Ch} †	0.0111	0.0061	0.0110	0.0085
(Price Low)	(27.79)	(28.70)	(19.39)	(28.90)
β_{1Ch} †			0.0117	0.0079
(Price Middle)			(25.95)	(25.01)
β_{2Ch} †			0.0099	0.0070
(Price High)			(20.96)	(25.70)
β_{0Pr} †		0.0307		0.0242
(Price Low)		(17.45)		(16.56)
β_{1Pr}				0.0195
(Price Middle)				(14.47)
β_{2Pr}				0.0205
(Price High)				(12.96)
β_{0Sh} †		0.0419		0.0379
(Price Low)		(19.88)		(16.13)
β_{1Sh}				0.0467
(Price Middle)				(14.87)

TABLE 4.3

Continued

Parameter	Model 1 Estimate	Model 2 Estimate	Model 3 Estimate	Model 4 Estimate
β_{2Sh} (Price High)				0.0597 (10.52)
α_1 (Dwave1)	0.2139 (7.29)	0.2129 (7.27)	0.2146 (7.32)	0.2157 (7.36)
α_2 (Dwave2)	-0.2539 (-10.31)	-0.2441 (-9.92)	-0.2547 (-10.33)	-0.2378 (-9.66)
α_3 (Dwave3)	-0.2641 (-11.34)	-0.2561 (-11.00)	-0.2660 (-11.42)	-0.2553 (-10.96)
α_4 (Dwave4)	-0.1349 (-5.22)	-0.1289 (-4.99)	-0.1358 (-5.25)	-0.1300 (-5.03)
α_5 (Dwave5)	-0.1125 (-4.67)	-0.0988 (-4.11)	-0.1130 (-4.69)	-0.0935 (-3.88)
α_7 (Dredsn)	0.4891 (5.72)	0.4820 (5.65)	0.4968 (5.80)	0.4639 (5.43)
α_8 (Experience)	-0.0011* (-2.22)	-0.0015 (-2.89)	-0.0011* (-2.21)	-0.0015 (-2.87)
α_9 (Dboat)	-0.1507 (-9.96)	-0.1698 (-11.16)	-0.1532 (-9.88)	-0.1964 (-12.58)
Log Likelihood	-26938.4	-26712.5	-26931.1	-26645.9
Schwarz BIC	26991.8	26774.1	26992.7	26732.1
Degrees of Freedom	3681	3679	3679	3673

Notes: Variable names and t-statistics in parentheses. Ch=Charter, Pr=Private, Sh=Shore, and Low, Middle, and High indicate income groups, respectively. All price terms enter the model with a minus sign, so a positive sign is consistent with the usual expectation of the price coefficient in demand models.
* significant at 5%, all other estimates are significant at 1%.
† In models 1 and 3 the price coefficients are not mode specific. In model 2 the price coefficients are for all income levels.

The signs on the estimated coefficients for the prices are all negative and significant with exception of the charter price. They appear to be positive in Table 4.3 because in estimation all are subtracted from other terms (see equation [4.9]). Hence, an increase in trip costs, such as through the imposition of a user fee, would be expected to lead to a reduction in the probability of using that mode. Comparing the price coefficients across income levels, e.g., β_{0Ch}, β_{1Ch}, and β_{2Ch}, we find relatively little difference, with the largest differences being within the shore angler mode group, where the high income category coefficient (0.06) is 37% larger than the low income category coefficient (0.038). Across the modes, however, there is striking difference in the responsiveness to price, indicating greatly different slopes depending on the mode of fishing. The charter coefficients are very small, but the private coefficients are about three-times larger and the shore coefficients are over two times larger than private ones. As we discuss in more detail below, these differences across modes indicate that anglers who participate in shore fishing are much more responsive to price changes than other fishermen.

All mode characteristic constant terms in the mode decision (α_{0Ch}, α_{0Pr}, and α_{0Sh}) are significant and positive, implying that anglers can get utility benefit from fishing trips. The positive estimate of the catch rate variable indicates that anglers will likely choose a mode that provides them with more catches. The coefficients in the probability of not fishing equation [4.14], i.e., α_0, to α_9, are also significant and give us appropriate interpretation. If the signs of these estimates are negative, it implies that anglers are more likely to going to fish instead of staying at home. For example, with negative signs of the experience variable and the dummy variable of owning a boat, more experienced anglers and/or anglers who own a boat will have higher possibility of taking a trip.

Evaluating the estimated probabilities at the means of all explanatory variables, Table 4.4, the predicted number of recreational trips to the Gulf states and probabilities of choosing modes by using the estimates are presented. The expected number of trips over the period are equal to 61×(1-π_i^{nf}), and the expected trips for each mode are calculated by 61×(1−π_i^{nf})×(π_{mi}^{f}). The probability of not fishing on any given day is estimated at 97.1 percent, on average. The number of trips that a representative angler would take to catch red snapper over the two-month period is estimated at 1.76 trips, and on average 1.15 of these would be from a private boat. Charter boat fishing is much less frequently done, with only 0.44 trips on average over the observed period.

TABLE 4.4

Predicted Trips per Two-Month Period and

Daily Probabilities of Choosing Mode and Not Fishing

Trips	Total	Charter	Private	Shore
Mean	1.755	0.439	1.152	0.164

Probability	Not Fish	Charter	Private	Shore
Mean	0.971	0.094	0.656	0.250

Note: Hereafter, all trips are defined as recreational trips *to catch red snapper* per two-month period.

The Effects of Income, Season, and Price on Trips, across Modes

Using the estimated coefficients, we predicted the number of trips in each mode for the different income categories, *i*.e., low (L), middle (M), and high (H) income groups, in table 4.5 Notice that the demand for fishing trips actually falls slightly as income rises from a high of 1.79 trips/two-month period for people in the low income group, to 1.68 trips for those in the higher group. Although one might expect fishing to be a luxury good (suggesting that trips rise as income rises), there are clearly other economic factors at play that are not captured in the model. The negative effect of income on fishing demand may be due to omitted choices. Thus, the set of feasible alternative recreational options increases as income rises. More noticeable are the differences in the modes chosen across income groups. Although we predict that individuals of all income will primarily take trips on private boats, only higher income people are predicted to prefer charter fishing, (0.157 (L) to 0.211(H) on average), while shore fishing is preferred by lower income people (0.555(L) to 0.265(H) on average). Hence, the model predicts substantial variability in choices made depending on income level.

TABLE 4.5
Predicted Trips per Two-Month Period and Daily Probabilities for Different Income Categories

Average Predicted Trips		Total	Charter	Private	Shore
Low Income	less than $35,000	1.791	0.157	1.079	0.555
Middle Income	$35,001 to $75,000	1.782	0.163	1.237	0.382
High Income	greater than $75,001	1.678	0.211	1.202	0.265
Probabilities		Not Fish	Fish (probability of each mode on a trip)		
			Charter	Private	Shore
Low Income	less than $35,000	0.9706	0.088	0.602	0.310
Middle Income	$35,001 to $75,000	0.9708	0.092	0.694	0.214
High Income	greater than $75,001	0.9725	0.126	0.716	0.158

The predicted number of trips and probability of not fishing across two month fishing periods are tabulated in table 4.6. The expected number of trips is the largest during the months of May and June. March and April are also preferred months and the least preferred fishing season is winter in the months of January to February.

TABLE 4.6

Average Predicted Trips across Waves

Trip	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	0.116	0.182	0.185	0.164	0.158	0.144
Private	0.894	1.398	1.422	1.257	1.213	1.106
Shore	0.311	0.487	0.495	0.438	0.422	0.385
Total	1.321	2.066	2.102	1.858	1.793	1.635

Fee Impacts

We now use the model to predict how fees can be used to reduce recreational fishing effort, which in turn, may reduce adverse impacts on the fishery. Suppose a day-based fishing permit fee were imposed on those who go fishing, equally charged to all anglers no matter what mode they use. Table 4.7 shows that the model predicts that fishing behavior would be quite sensitive to such an increase in the cost of a fishing day. We estimate that a $5 fee would lead to a 12% reduction in total fishing effort and a $20 fee is predicted to reduce trips by 38% which is 1.1 trips every two months. Among modes, charter boat fishing demand is least affected and shore fishing is most affected. If the fee is increased to over $15, the model predicts that half of the least expensive mode, shore fishing, will be eliminated. In contrast, the same increase in costs for charter fishermen has a relatively small effect.

TABLE 4.7

Predicted Trips per Two-Month Period after Fee Is Imposed and Increases

	Trips per two-month period			
Daily Fee	Total	Charter	Private	Shore
$0	1.7994 (0.0%)	0.1583 (0.0%)	1.2171 (0.0%)	0.4240 (0.0%)
$5	1.5850 (-11.9%)	0.1513 (-4.5%)	1.0949 (-10.0%)	0.3389 (-20.1%)
$10	1.4040 (-22.0%)	0.1449 (-8.5%)	0.9876 (-18.9%)	0.2715 (-36.0%)
$15	1.2504 (-30.5%)	0.1391 (-12.2%)	0.8932 (-26.6%)	0.2182 (-48.5%)
$20	1.1196 (-37.8%)	0.1339 (-15.4%)	0.8099 (-33.5%)	0.1758 (-58.5%)
$25	1.0076 (-44.0%)	0.1293 (-18.3%)	0.7364 (-39.5%)	0.1420 (-66.5%)

Note: Percentage Declines in Parentheses.

The distribution of these impacts across the modes make intuitive sense; as a percentage of the trip price that they already face, a five dollar fee has much greater significance to shore fishermen than to charter fishermen. We find, therefore, that a price instrument such as a fee and TRs to rationing would have the effect of favoring charter fishing, the pastime of the wealthy, relative to shore fishing which is the choice for the lower income anglers.

User fees are particularly attractive from an efficiency perspective because they restrict fishing opportunities in a way that those who value the resource most (in terms of willingness to pay) are the ones who end up using the resource. Fees are more efficient than the current policy of closures and based on our results, we find that a user fee can be very effective in reducing fishing effort. However, we find that such a policy may not be desirable on equity grounds. A flat fee will work by reducing fishing pressure by the lower income participants who use the least expensive mode, essentially excluding this group from access to the resource. Balancing efficiency and equity in practice is a challenge, but ignoring the issues either explicitly or implicitly through the choice of the model, will not make this challenge go away.

Consumer Surplus

Because our utility function is assumed to be linear in income (or budget) and catch rates, consumer surplus of taking a trip using mode *m* is equal to compensating variation (CV). If we assume taking a trip can not cause an individual to jump income categories, i.e., low income to middle income group, this welfare measure will be same as equivalent variation (EV). Our interest is in measuring how much an angler can benefit when taking a trip to catch red snapper using mode *m*. Expected per-day (per-trip) consumer surplus (CS) when an angler takes a trip using mode *m* is defined implicitly by the equation

$$U_m(B - P_m - CS_m) = U_0(B),$$

and empirical expression using estimates is

$$E(CS_m)/day = \frac{\alpha_m - \alpha_0 + \gamma \cdot CR_m}{\beta_m} - P_m,$$

where β_m is price parameter for each mode *m*, and other parameters and variables are same as defined above. Gross per-day CS for mode *m* when an angler take a trip using mode *m* is approximate as $(\alpha_m - \alpha_0 + \gamma \cdot CR_m)/\beta_m$, and net per-trip CS can be measured by subtracting the cost of fishing from the gross CS. Because estimated marginal utility of income varies by income group, we can compute the welfare measures by both income group and mode. Per-day CS estimates calculated by using the estimated parameters for each mode and by evaluating variables at the mean are presented in Table 4.8.

TABLE 4.8

Expected Consumer Surplus per Day across Modes

	Gross E(CS)/Day			Net E(CS)/Day		
Income Group	Charter	Private	Shore	Charter	Private	Shore
Low	398.2	179.5	93.6	135.4	127.1	63.6
Middle	426.7	223.2	76.0	163.9	170.8	46.0
High	479.7	211.5	59.4	216.9	159.1	29.4
Weighted Average	418.3	201.1	82.8	155.5	148.7	52.8

Expected per-trip CS is biggest when a charter boat trip is taken while it is smallest when shore fishing is chosen in both gross and net terms. Whenever an angler takes a charter boat trips, he can get $156 for his welfare benefit. If an angler takes a trip using his private boat or fishes at shore, his welfare gain will be $149 and $53, respectively. The reason the difference of CS between charter and private boats is not significantly large is that the fixed (or sunk) cost of owning a private boat is not captured when we calculate the price. If we could appropriately add this fixed cost to the price of taking a private boat trip, the net CS for private boat trip would diminish.

TABLE 4.9

Expected Consumer Surplus per Day across Two-Month Periods

Gross E(CS)/Day	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	378.4	434.3	436.5	421.0	416.5	405.0
Private	184.6	205.4	206.2	200.4	198.8	194.5
Shore	73.9	84.3	84.7	81.8	81.0	78.8
Weighted Average	167.3	187.1	187.9	182.4	180.8	176.7

Net E(CS)/Day	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Charter	115.6	171.5	173.7	158.2	153.7	142.2
Private	132.2	153.0	153.8	148.0	146.4	142.1
Shore	43.9	54.3	54.7	51.8	51.0	48.8
Weighted Average	111.3	131.2	131.9	126.4	124.8	120.8

Because α_0 captures seasonal dummy variables, CS can be measured for each 2-month period (Table 4.9). If the marginal utility of income is constant over the range of the price change, β_m for each mode m can be calculated by the weighted average of marginal utility by income category. When an individual take a trip in May and June, she can get the highest per-day CS for all modes. When taking a trip using charter boat, private boat, and at shore in this period an angler can get \$174, \$154, and \$55, respectively. On the other hand, January and February are least desirable period because anglers obtain the smallest welfare gain.

Concluding Remarks

Overfishing is a serious problem in fisheries throughout the world and there is increasing recognition that recreational as well as commercial fishing must be controlled. Standard economic logic suggests that limiting catch using a price mechanism would be more efficient than other rationing mechanisms. However, a price instrument, such as an access fee or a transferable right, would raise the price of fishing to all anglers. Such a policy would clearly have more significance to those on the lower end of the income distribution than to those on the upper end. Furthermore, a flat fee or price increase would also affect the types of modes equally, but the impact would differ widely. Compared to the normal costs of day trip, a small fee can amount to a high percentage tax on some modes and a relatively small tax on others.

Using results from an econometric model that allows for differing price responses across modes and income groups, we consider the consequences of a per day user fee on recreational fishing in the Gulf of Mexico. The model used for this analysis is based on the approach taken by MSR (1991), which is appropriate when complete trip data are not available, but our model extends the MSR (1991) approach in that it allows the price coefficient to vary across incomes and modes. We find income to be an important determinant of mode choice. Our results indicate that a user fee would have much greater impacts on low income groups, than on higher ones and would affect low-cost fishing modes much more than it would modes that are relatively expensive.

We also compute per-day CS across modes and two-month periods. When an angler takes a trip using charter boat he will get the largest welfare gain. Per-day CS varies by seasons. A trip in May and June will allow anglers to have the biggest CS while a trip in January and February is lease preferable in terms of welfare measures. For the case of the recreational fishery of the Gulf of Mexico, we estimate a model that provides information that can help guide a policy based on both efficiency and equity. In the next chapter we will use this model in order to simulate the impact of a recreational TR program.

CHAPTER V

SIMULATION ANALYSIS OF TRANSFERABLE RIGHTS PROGRAM

The purpose of this chapter is to develop a simulation model that will be used to conduct an economic analysis of transferable rights program aimed at reducing over-use of the Gulf of Mexico red snapper (GRS) fishery. The main focus will be on explaining general framework of how the TR program will be applied in the simulation analysis. A TR program can play a role in restricting the harvest of recreational red snapper fisheries, thereby increasing the red snapper stock to a level which will ensure its sustainability. A simulation approach is adopted to evaluate both biological and economic effects of the TR policy on the fishery. We will use the General Bioeconomic Fisheries Simulation Model (GBFSM) as a simulation tool. Because the model is under development as of November 2006, this chapter will serve to state how a submodel of the TR program will be constructed and present some preliminary results. An empirical model of representative anglers' demand for TRs will be formulated, which then is incorporated into the GBFSM.

This chapter has four objectives: (1) to develop a general framework and a simulation submodel to implement the TR program for the GRS fishery, (2) to show how we can assess the potential benefits or costs of moving toward a TR program in the Gulf red snapper fisheries in terms of total surplus, (3) to present how the TR market can be simulated for various scenarios of TAC can be found, and (4) to provide some preliminary results from GBFSM with the incorporated TR submodel.

Background

To achieve the research objectives of this dissertation, a simulation approach will be adopted as the primary tool of analysis. A simulation model can be designed to account for the biological and economic interdependencies between two or more fisheries, e.g., red snapper fishery is closely related to shrimp fishery and other reef fish fisheries because bycatch problem occurs when other reef fish is caught and some instruments of harvesting shrimp fishery are used.

The GBFSM is used to conduct the simulation analysis.[17] The GBFSM was developed to predict how alternative management policies would affect annual crop fisheries (Grant et al. 1981; Isaakson et al. 1982). The simulation model and modified versions have been used extensively for analyzing the effects of management policies in the Gulf of Mexico (Blomo et al. 1978; Blomo et al. 1982; Grant and Griffin 1979; Griffin and Stoll 1981; Griffin and Hendrickson 1992; Griffin and Oliver 1991; Griffin et al. 1993). The GBFSM consists of two main parts: a biological submodel and an economic submodel. The biological submodel represents the recruitment, growth, movement and mortality of shrimp and finfish. Mortality of shrimp and finfish is due to

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[17] This section is taken from the proposal of MARFIN grant #NA17FF2873, Griffin, W. L. and R. T. Woodward. 2002. “Bioeconomic Analysis of the Red Snapper Rebuilding Plan and Transferable Rights Policies in the Gulf of Mexico.” Texas A&M University, College Station. The authors, co-chairs of my committee, approved of my using the proposal.

both natural causes and fishing. In addition to harvests of shrimp and reef fish, effort targeted toward the shrimp also leads to incidental bycatch of reef fish. When a management policy is imposed on GBFSM, the biological submodel calculates the changes in days fished, number of vessels and landings of shrimp and red snapper. The economic submodel then calculates the monetary impact on fishermen in terms of costs, revenues and rent for each vessel class in each area based upon the biological effects of the management policy implemented. GBFSM has also been modified to incorporate values for the consumers' surplus associated with the recreational fishery (Gillig et al. 1998).

The economic criterion used to judge a policy is based on the discounted total net economic surplus of the directed red snapper and shrimp fisheries. The larger the discounted total net surplus, the more preferable the policy is from an economic point of view. Real discount rate rather than a nominal discount rate will be used to calculate the present value. The real discount rate refers to a nominal rate that has been adjusted to exclude expected inflation. To maintain consistency with prior analysis, the real discount rate to be used in this analysis is 7.0 percent, as suggested in the Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (1992).

The discounted net total surpluses (TNS) is represented by the following equation,

$$TNS = CS_S + CS_{CR} + CS_{RR} + PS_S + PS_{CR} + PS_{RR}$$

where $CS_S = \sum_{t=0}^{T}\left(\frac{CS_{S_t}}{(1+i)^t}\right)$, $CS_{CR} = \sum_{t=0}^{T}\left(\frac{CS_{CR_t}}{(1+i)^t}\right)$, $CS_{RR} = \sum_{t=0}^{T}\left(\frac{CS_{RR_t}}{(1+i)^t}\right)$,

$$PS_S = \sum_{t=0}^{T}\left(\frac{PS_{S_t}}{(1+i)^t}\right),\ PS_{CR} = \sum_{t=0}^{T}\left(\frac{PS_{CR_t}}{(1+i)^t}\right), \text{and } PS_{RR} = \sum_{t=0}^{T}\left(\frac{PS_{RR_t}}{(1+i)^t}\right) .$$

TNS is the sum of the discounted consumer and producer surpluses of the commercial and recreational red snapper fishery and the shrimp fishery for a given management policy. CS_{S_t}, CS_{CR_t}, and CS_{RR_t} are discounted consumer surpluses of the shrimp, commercial red snapper, and recreational red snapper fisheries, respectively. PS_S, PS_{CR} and PS_{RR} are the discounted producer surpluses of the shrimp, commercial red snapper and recreational red snapper fisheries, respectively. i is the discount rate which is 7.0 percent and t is the simulation time period which goes from 0 to T years.

A version of the GBFSM calibrated to consider policies affecting shrimp, red snapper, and other reef fish species is currently under development. This model will also account for various forms of recreational effort in the Gulf. Upon completion of this version of the GBFSM, the subroutines to simulate TR program will be incorporated into the main simulation model. The flow of the GBFSM is presented in Figure 5.1. Given a TAC from the policy sector of GBFSM, the TR subprogram will predict the number of trips by fishing modes, months, and species. Species are categorized by only red snapper and other reef fisheries. The TR submodel will return a new set of catchablility coefficient (q_{ajm}^{1TR}) into the current structure of the GBFSM that account for the fact that recreational fishermen can target red snapper throughout the year, though at a reduced intensity.

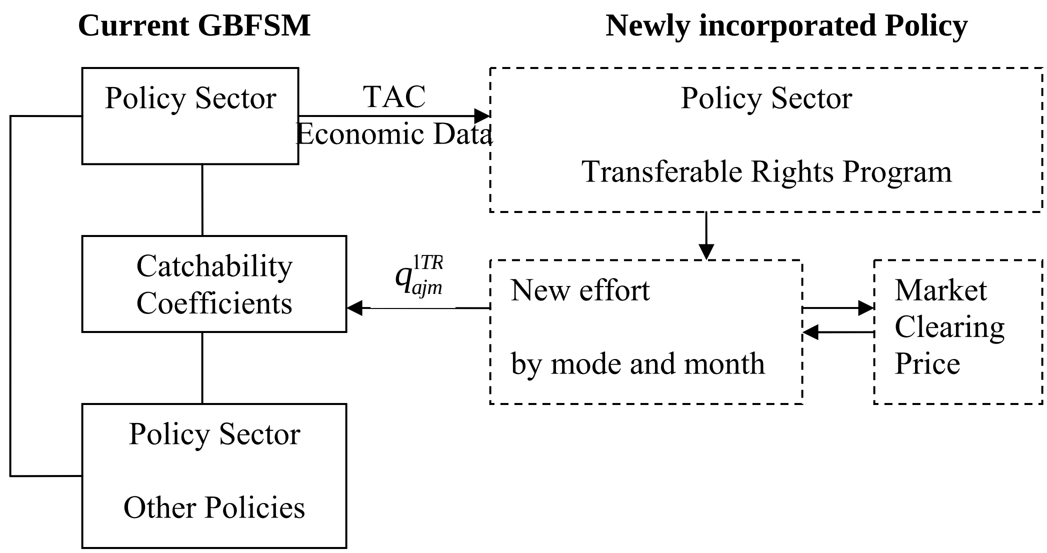

FIGURE 5.1

Flow Chart of Simulation Analysis for TR program

In the rest of this chapter we develop the conceptual foundations for these subroutines and the assumptions that are used. We describe in detail the modeling approach that will be incorporated into the full simulation model. We also consider the possibility of trading TRs between recreational and commercial sectors when TR program is introduced to both sectors. Based on partial results of developed submodel, the TR program in the GRS fishery focusing highly on recreational sector will be evaluated.

Conceptual Model of Transferable Rights Program

As we reviewed in chapter II, TR programs have been used in various areas to protect environment and resources. These programs specify a predetermined total level of quotas (permits) within a specified region. Permits equal to the permissible TAC are distributed among fishermen in the region. Such programs could include both the recreational and commercial fishing sectors. To ensure that such permits serve their purpose as incentives to achieve socially desired levels, total harvesting levels within a given region are limited so that the permits become valuable. Economic efficiency can be increased through trading of rights within the sector or across sectors. Our application is made to the red snapper fishery in the Gulf of Mexico.

Transferable Rights Program in Only Recreational Sector

In this section we elaborate how the recreational TR program works to achieve a given TAC goal. In simulations of the recreational sector, fishing trip demand is usually predicted as a function of travel cost. This demand can easily be converted to pounds of fish assuming for simplicity that catch rates and pounds per fish remain constant. The assumptions of constant catch rates and constant pounds per fish are obviously quite strong and ignore the fact that the behavior of the average angler may change as a result of the TR program. However, for lack of data on these behavioral responses and since we recommend that that bag limits be retained, our results can be thought of a first approximation of a TR program for the red snapper fishery. Traditionally recreational catch limits have been achieved by closures and size and bag limits. However an equivalent reduction can be achieved using a price instrument.

In figure 5.2, the aggregate demand of the TR permits is given by additional cost of trip (P_{TR}), which represents how much anglers are willing to pay to take an additional trip. For example, if anglers are paying \$100 to take a trip on average, the total quantity demanded will be decided at point C. We assume here that this results in an overfishing situation and that the catch needs to be reduced to Q* pounds to satisfy the TAC. This reduction can be achieved if anglers pay P_{TR} to purchase a TR permit at point A to achieve the TAC goal.

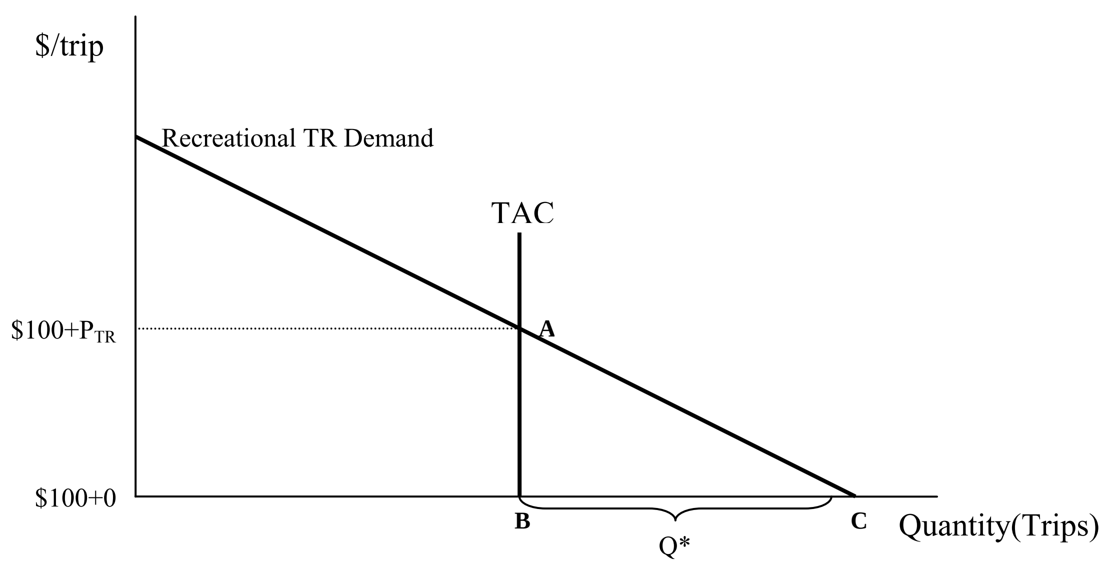

FIGURE 5.2

Recreational Transferable Permit Demand and the Substitution Effect

Because we consider a case in which there is a TR program only for red snapper, it is likely that implementing such a program will result in some degree of substitution away from red snapper. A substitution effect is defined as the percentage of anglers who will give up catching one species and switch their target to other species. With substitution effect, the demand curve in figure 5.2 will shift down and the possible optimum of the price of TRs will be decided between points A and B. Hereafter in this chapter the estimated demand curve will incorporate the substitution effect. Unfortunately, because most travel-cost data do not distinguish costs targeting red snapper from costs targeting other fisheries, no substitution effect between species is found in the standard recreation demand models (including that estimated in the previous chapter). The details of how we approximate a substitution effect for our simulation model will be explained below.

Net Benefit of Transferable Rights Program

Closures are mainly used for the current policy to manage the number of trips of the GRS fishery. As of 2006, the recreational season for GRS fishery is closed from January to April 20 and from November through December. This policy will lead to an inefficient outcome because, as we have seen in chapter II, recreational anglers demand to go fishing during the closed season. Under a TR program they can go fishing whenever they want with the permit purchased. Figure 5.3 presents demands with the substitution effect in both closed and open seasons.

We use the Marshallian demand to calculate welfare measures. Consumer surplus, which is a Marshallian measure, has dominated applied work because of the difficulty of obtaining Hicksian measures which are often called “exact” measures; utility functions are difficult to observe in the real world.

Suppose a simple two-period demand system in which demand of trips in the first season is currently closed is presented in the left panel of figure 5.3. After implementing the TR program, an equilibrium price of P_{TR} is reached leading to demand throughout the year. For the previously closed season, area A will be the benefit moving from the closure policy to TR program. For the open season area C will be the loss because there will be an increase in the cost (P_{TR}) to purchase the TR permit. The efficiency gain from the current closure policy to the TR program will be the area A-C.

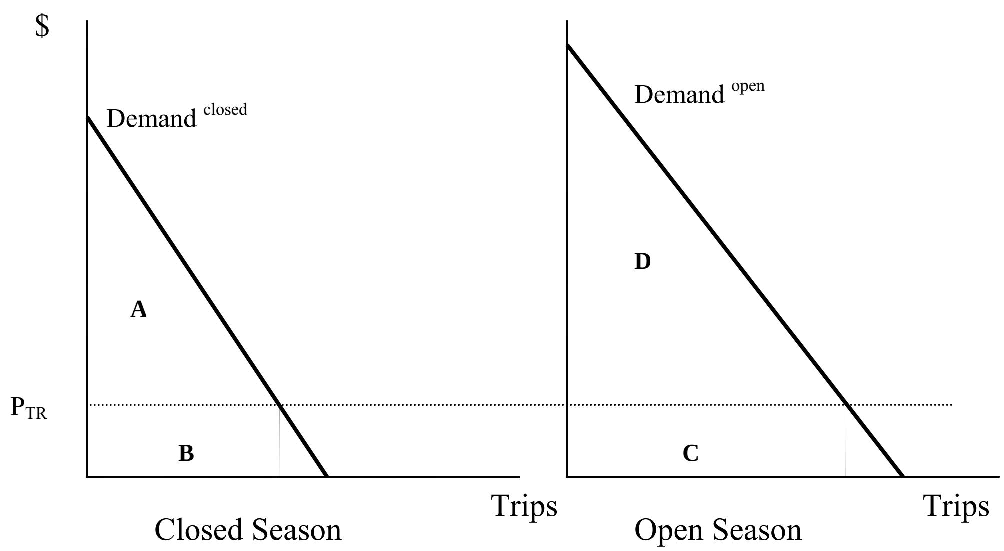

FIGURE 5.3

Efficiency Gain of Transferable Rights Program

Transferable Rights Program in Both Recreational and Commercial Sectors

Although some negative consequences of transfer of the rights between commercial and recreational sector are discussed in chapter II, allowing trading between sectors can lead to an efficiency gain. In this section we will explain why the efficiency gain by trading rights between sectors arises and how the new price and allocation are determined.

With no tradable permit market, initial allocation of the TAC between sectors matters. Efficiency is only achieved if the TAC allocation is set such that the marginal benefit to each sector the same. Before we move on to the full model of TR programs in both recreational and commercial sectors, we consider appropriate initial allocation of TR quotas (permits) between commercial and recreational harvesters to insure that the public's resources are used efficiently. The main problem is how to allocate the TAC between two sectors. For economic efficiency, those who value the fish most should obtain more of the TAC. The values for the fish can be captured by demand such as trip demand and quantity demand.

In the recreational sector, as we explored above, a recreational demand model can be used to derive the demand for the TAC. For the commercial sector, demand for the TAC is a function of the profits that can be obtained from the sector's share. In the simplest case, considered here, the demand would be determined by the marginal profits that could be generated by the TAC, $\pi(q) = p(q) - c(q)$, where q is the TAC allocated to the commercial sector, $p(q)$ is the inverse demand curve for red snapper and $c(q)$ is the marginal cost of harvesting. Even if $c(q)$ is constant, the downward sloping demand curve will cause the sector's demand for TAC to be downward sloping.

Demand for a share of the TAC by each sector would typically be downward sloping so that an increase in the trip cost would lead to decease in fishing effort directed toward red snapper. Commercial and recreational demand relationships would capture how much the two sectors are willing to pay for a marginal increase in their share of the TAC. Once the TAC is set, it can be interpreted as a fixed supply curve.

Graphical representation to determine how we allocate the total TAC between two sectors is shown in figure 5.4. The negatively sloped curves of panel A to C are demand for two sectors, A and B, and an aggregate demand curve which is the horizontal aggregation of demands A and B. The point where the aggregate demand curve meets total TAC in panel C provides the marginal value of the TAC to the economy under an optimal allocation. Thus, this establishes a procedure for measuring total benefits, and a means of identifying the efficient allocation between the two sectors.

The optimal allocation for sector A occurs at point a where the sector's demand corresponds to the given level of cost, P^*, obtained in panel C. In the same fashion, optimal allocation for sector B is determined at point d where demand meets P^*. However, if the actual allocation for each sector is made at points b and c, then the result will be inefficient. In this example, sector A needs to have a smaller allocation and sector B needs to have a greater allocation to achieve maximum of total surplus. However, the result of allocation is dependent on the slope and intercept of each curve.

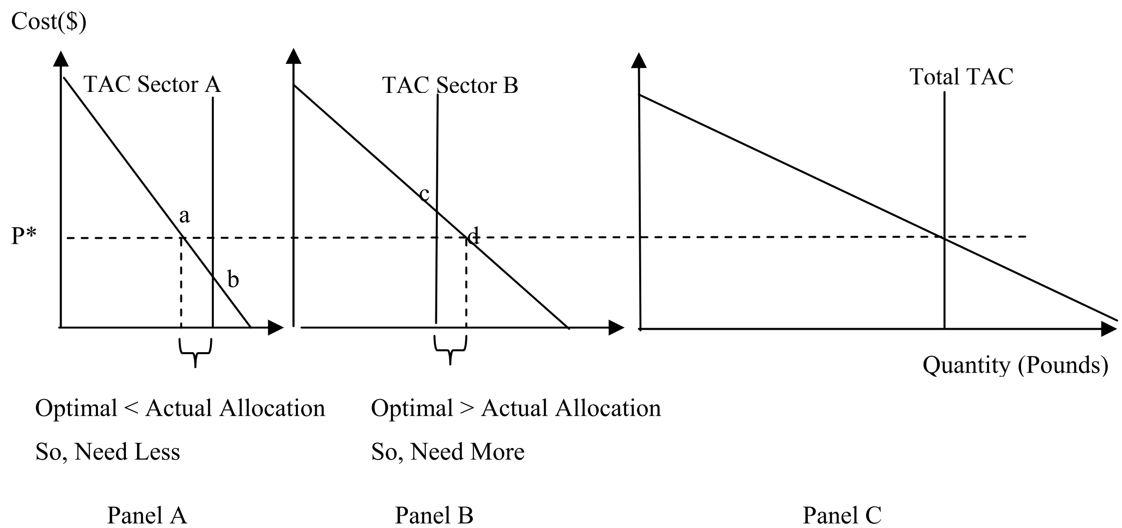

FIGURE 5.4

Initial Allocation of TAC between Two Sectors

Montgomery (1972) showed that the initial allocation of permits is not a significant problem under the tradable market system with assumption of zero transaction costs and a competitive market. With tradable permits a sector that wants less or more permits can sell or buy the permits to the others and the efficient allocation is reached. Figure 5.5 suggests how to allocate red snapper TAC between sectors. By using recreational and commercial fishing demand, we can predict the optimal allocation between two sectors under the TR program in both sectors.

The lines in figure 5.5 depict the recreational and commercial demand toward quotas (permits) for each of the two sectors. The recreational demand is read from left to right and the commercial demand is to be read the other way around. In order to achieve a TAC goal given to the recreational sector, recreational angers should pay \$$P_{TR}$ to purchase a TR permit. Suppose the marginal cost to commercial fishermen is constant at C. Two possible demand curves are shown, one in which the choke price is high, $\overline{P}_H = P_H - C$, and a second for a lower choke price, $\overline{P}_L = P_L - C$. These different red snapper prices lead to the two demand curves for the TAC as shown with choke prices P_H and P_L. If the price of red snapper is high the equilibrium price per unit of the TR (P_A) is above P_{TR}, then commercial fishermen will want to buy more permits from the recreational sector. The maximum of permit transfer from recreational to commercial sector is Q_A. On the other hand, if the price of red snapper is low, the new equilibrium price of the TR is determined below P_{TR}, commercial fishermen will sell their permits to recreational anglers rather than harvest red snapper. No matter what share of the TAC is initially allocated, both sectors can achieve the objective of maximizing the net benefit following the above mechanism to the equilibrium price in the permit market.

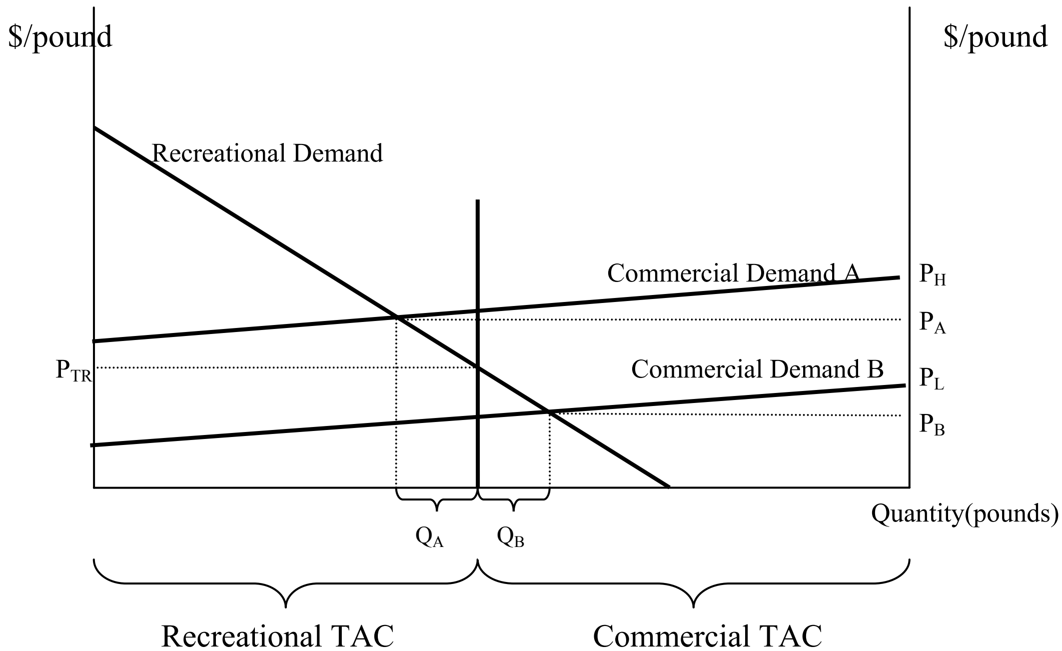

FIGURE 5.5

Optimal and Actual Allocation of TAC between Sectors

Submodel for Transferable Rights Program

This section describes empirical issues that must be addressed to construct a simulation submodel of the TR program for the GRS fishery. Empirical representation of the recreational demand by fishing mode and assumptions that we use are introduced. An equilibrium condition will be shown under the TR program, and finally how to link the submodel of TR program to the main GBFSM will be stated.

Recreational Demand and Assumptions

In chapter IV we estimate a discrete choice model of marine recreational fishing demand, allowing for differing price/fee responses across fishing modes and monthly seasons. This econometric model is an important piece of the submodel we develop to simulate a recreational TR program. The trip demand is directly equivalent to the day-based TR demand as shown in the Chapter III. The number of recreational *m* mode trips in *i* month can be written

$$Trip_{im} = \{1 - \pi_i^{nf}(p_m)\} \cdot \pi_m^f(p_m) \cdot (1 - SR(p_{TR})) \cdot Day_i,$$

where p_m is the price of trip, p_{TR} is the price of TR, 1-$\pi_i^{nf}(p_m)$ is the probability of fishing to target the red snapper in *i* month, $\pi_m^f(p_m)$ is the probability of taking a *m* mode trip estimated in chapter IV,[18] *SR(p)* is the substitution rate switching targets from red snapper to other species, and Day_i is the number of possible fishing days in *i* month (e.g., 31 in January).

The assumptions that we used to develop the TR demand are as follows:

1. The recreational fishing trip demands and mode choice structures are same for all Gulf States.

[18] Because the probability of taking a trip using *m* mode ($\pi_m^f(p_m)$) does not vary by species, our econometric model overestimates the percentage of using private boat and underestimates the percentage of using head and charter boats. In case of red snapper for-hire boats are more likely used for recreational trips. In order to well predict the probability of taking a trip using each mode compared with the red snapper historical data, adjustment weights are used. Decision criterion for the weights was the seven year averages (1993-2001) of red snapper catches for each mode.

2. Because we estimate the demand for two-month periods we assume the probabilities of taking a trip in two months in the same wave as defined in chapter IV are same (e.g., $\pi_i^{nf}(p_m)$ in January and Feb is same).
3. Because red snapper cannot be easily caught inshore we dropped shore fishing mode. Head boat trips are added because the GBFSM contains this type of mode (vessel class).
4. We assume that the head and charter boats sectors are perfectly competitive so that all rents generated by the TR market accrue to the anglers.
5. The substitution rate is same for all fishing modes.

Demand of Head Boat

Regarding the third assumption of the added head boat mode, we were forced to estimate head boat demand because the MRFSS data set does not include head boat trips. To approximate head boat demand, we use a weighted average between estimated coefficients of charter boat and private boat. Intercept and slope coefficients of charter and private boats are estimated in chapter IV.

$\alpha_{HB} = \gamma \cdot \alpha_{CB} + (1-\gamma)\cdot \alpha_{PB}$, and

$\beta_{HB} = \theta \cdot \beta_{CB} + (1-\theta)\cdot \beta_{PB}$,

where α_{HB}, α_{CB}, and α_{PB} are intercept parameters for head, charter, and private boats, respectively, and γ is the weight of its parameter. Similarly, β_{HB}, β_{CB}, and β_{PB} are slope (price) parameters for each mode, and θ is its weight. The optimal weights (γ and

θ) were found by minimizing sum of squared error (SSE) of the percentage ratio of head boat, charter, and private-rental modes. We used average percentages of fishing efforts (trips)[19] for 7 years and chose γ and θ to minimize SSE.

$$\underset{\gamma,\theta}{SSE} = \sum_{m}\left(\hat{\pi}_m(\alpha_m, \beta_m; \gamma, \theta) - \overline{\pi}_m \right)^2,$$

where $\hat{\pi}_m(\cdot)$ is the predicted probability of taking a trip using *m* mode, and $\overline{\pi}_m$ is the average of the probability of using *m* mode. Predicted parameters, α_{HB} and β_{HB}, that minimize the SSE will be incorporated into the recreational demand model. The demand model has three modes: head, charter, and private boats.

Substitution Rate

As noted above, because we consider a case in which there is a TR program only for red snapper, it is likely that implementing such a program will result in some degree of substitution away from red snapper. The substitution rate, *SR(p)*, is defined as the percentage of anglers who will give up fishing red snapper and target other species instead. If *SR* is equal to zero there is no substitution effect. For example, if *SR* equals to 0.1 then 10% of red snapper trips will switch into trips to target other species. In order to have the substitution effect in the model, we need a cross-price elasticity that tells us how the demand for trips targeting other species will change with respect to the price of

[19] The GRS recreational fishing data are obtained from the National Marine Fishery Service (NMFS) MRFSS data, the NMFS Head Boat Survey data, the Texas Wildlife and Park Department, and the NMFS Southeast Regional Office.

taking a red snapper trip. Such cross-price elasticity is not estimated in our recreation demand model and we could not find this estimated elsewhere in the literature.

However, we were able to estimate this variable using results from Gentner (2004). Gentner estimates target substitution elasticities for the catch rate changes in one species using the MRFSS data including the Gulf coasts. The cross-price elasticity is not available, but he does provide substitution of species with respect to the catch rate which we can build on to derive our cross-price measure. Gentner(2004) provides substitution elasticities with respect to catch rate as follows:

$$\frac{\text{\% change in trips of other species}}{\text{\% change in catch rate of red snapper}} = -\varepsilon_1$$

$$\frac{\text{\% change in trips of red snapper}}{\text{\% change in catch rate of red snapper}} = \varepsilon_2 .$$

From the prediction of our model, we can have the own price elasticity

$$\frac{\text{\% change in trips of red snapper}}{\text{\% change in price of red snapper}} = -\hat{\varepsilon}_3 .$$

Finally, the cross-price elasticity can be written

$$\frac{\text{\% change in trips of other species}}{\text{\% change in price of red snapper}} = \frac{-\varepsilon_1}{\varepsilon_2} \cdot (-\hat{\varepsilon}_3) .$$

Using this cross-price elasticity of trips in other species with respect to the price of red snapper trips, we can incorporate the substitution effect into the model and predict how much percentage of anglers who used to target red snapper would go fishing for other species if there is an increase in the price only for the red snapper. The substitution rate, which is a function of permit price (P_{TR}), will be $\left\{ \frac{-\varepsilon_1}{\varepsilon_2} \cdot (-\hat{\varepsilon}_3) \cdot \frac{\overline{\mathrm{Q}}_{\mathrm{other}}}{\overline{P}_{RS}} \cdot \frac{1}{\overline{\mathrm{Q}}_{\mathrm{RS}}} \right\} P_{TR}$, where

$\overline{Q}_{other}$ is the number of trips for other species, $\overline{Q}_{RS}$ is the number of trips for red snapper, and $\overline{P}_{RS}$ is the price of taking a trip for red snapper. These three variables are evaluated at the means.

Commercial Demand

As noted above, efficiency is increased if it is possible to trade TRs between the recreational and commercial sectors. The problem is how precisely we can estimate the commercial demand. However, it would be quite difficult to estimate commercial fishing demand because it needs to be a multi-equation system demand model between species to reduce estimation biases. The commercial snapper demand was previously estimated by Park (1996) in his Ph.D. dissertation at North Carolina University using 1977-1992 National Marine Fisheries Service (NMFS) data. The study analyzes six broad types of commercial fisheries: Groupers, Porgies, Snappers, Jacks, Tilerfishes, and Sea basses.

As in previous versions of GBFSM, we adopt Park's commercial snapper demand and its corresponding price flexibility as a proxy of the commercial red snapper demand in the Gulf. Following Park's results from the synthetic inverse demand system (SIDS) model, the price flexibility of snappers is -0.0341. That indicates 1 % increase in red snapper landings would result in a 0.0341 % decline in its price. This price flexibility implies a highly elastic commercial demand, a result that seems inconsistent with observed price variation in the fishery in recent years. In light of this inconsistency, sensitivity analysis will be carried out with respect to the price flexibility.

Equilibrium Condition

Following the above recreational demand model, we can then measure daily fishing trip demand which is a function of the travel cost by three fishing modes and months. Because the TAC is denominated in pounds, we need to convert the demand for days to pound equivalents. This is done assuming constant catch rates per trip, average pounds per fish and total number of anglers who fish in the Gulf coasts. Catch rates per trip and average pounds per fish for each mode (head, charter, private-rented boats) are calculated using 7-year averages of them (see footnote 19).

The number of anglers is estimated by equating the predicted harvests based on our econometric model (trips×catch×anglers) and the 1997 reported harvests. The population of possible anglers (*POP*) is the reported harvests in 1997 divided by the predicted harvest per person per year. The number of anglers in the Gulf is then held constant after 1997:

$$POP_{2001} = \frac{\text{Reported Harvest}_{1997}}{\text{Predicted Harvest/person/year}},$$

At equilibrium, total landings should be equal to the given TAC by

$$TAC = \left\{ \sum_{i} \sum_{m} Trip_{im}(\overline{P_m} + P_{TR}) \cdot CR_m \cdot AP_m \right\} \cdot POP,$$

where $Trips_{im}(\cdot)$ is the number of trips using *m* mode in *i* month, $\overline{P}_m$ is the average trip cost, P_{TR} is the price of a unit of TR, CR_m is the catch rates of *m* mode, AP_m is the average pound of red snapper for fishing *m* mode, and *POP* is the total population to take a trip in the Gulf coasts. Fishing modes for the index *m* are head boat, charter boat, and private boat, and seasonal trips for the index *i* are measured by month from January (*i*=1) to December (*i*=12).

An analytical solution of the price given the TAC could not be directly obtained because the demand function is highly non-linear. However, we can use Newton's method to find a numerical solution of the marginal price corresponding to the given recreational TAC. Newton's method, also called the Newton-Raphson method, is a root-finding algorithm that uses the first few terms of the Taylor series of a function (usually nonlinear). If we want to find a root of *f(x)*, the algorithm can end up being applied iteratively to obtain

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}, \ (n=1,2,3\ldots\ldots).$$

The iteration process stops when $-f(x_n)\big/f'(x_n)$ is close to zero, so that x_n can be the root of the function. In our case, the root we want to get is P_{TR}, so that our function is

$$f(P_{TR}) = \left\{ \sum_i \sum_m Trip_{im}(\overline{P_m} + P_{TR}) \cdot CR_m \cdot AP_m \right\} \cdot POP - TAC,$$

and we want to find the solution of P_{TR} making the equilibrium condition hold by the algorithm, $P_{TRn+1} = P_{TRn} - \dfrac{f(P_{TRn})}{f'(P_{TRn})}$, $(n=1,2,3\ldots\ldots)$.

If we find the marginal cost per pound is \$1 for making recreational demand binding to the current TAC of 4.47 million lbs. for the GRS fishery, it implies a recreational angler needs to pay \$1 per pound more to achieve the TAC goal.

Linking the TR Submodel with GBFSM through Catchability Coefficient

In setting up GBFSM to analyze the TR policy for GRS fishery, a link between the simulation model and the empirically incorporated TR demand model should be developed to take account of the new policy. The TR program for GRS fishery will reduce total harvests of red snapper fishery but will increase those of other species because of substitution effects. These effects have been incorporated into GBFSM.

In the GBFSM the catchability coefficients capture the extent to which effort from different vessel types lead to harvests. These coefficients vary by fishing modes (vessel class), months, and age levels. Recreational harvest of *j* species in *a* age group can be defined as

$$h_{ja} = \sum_m q_{ajm} \cdot T_m ,$$

where *m*=mode, and T_m=trips for all species by mode. Under the closure policy of red snapper fishery, the catchability coefficient, q_{ajm} , is the weighted average of the percentage of open days (γ):

$$q_{ajm} = \gamma \cdot q^1_{ajm} + (1-\gamma)\, q^0_{ajm} = \gamma \cdot q^1_{ajm} + (1-\gamma)\, q^{closed}_j q^1_{ajm} ,$$

where q^1_{ajm} is the catchability coefficient when the season is open and q^0_{ajm} is the catchability coefficient when it is closed. q^{closed}_j is an adjustment factor in the closed season and is a small number reflecting bycatch of red snapper.

Under the TR program, γ is always equal to one, meaning that we can go fishing for red snapper all days of all months. Hence, the impact of the TR program is captured by computing a new value for q^1_{ajm} since a smaller portion of the trips will now target red snapper under the TR program. As the season is open for all other species as well as red snapper fishery, q^1_{ajm} is redefined as[20]

$$q^1_{ajm} = \tilde{S}_{jm} \cdot \tilde{q}^1_{ajm} + \left(1 - \tilde{S}_{jm}\right) \cdot \tilde{q}^0_{ajm} = \tilde{S}_{jm} \tilde{q}^1_{ajm} + \left(1 - \tilde{S}_{jm}\right) q^{closed}_j q^1_{ajm},$$

where $\tilde{S}_{jm}$ is the share of *m* mode recreational trips targeting species *j* (T_{jm}/T_m) when there is no cost of purchasing TR permit. $\tilde{q}^0_{ajm}$ is the catchability coefficient for those not targeting species *j*. We assume that the catchability coefficient for those not targeting red snapper, $\tilde{q}^0_{ajm}$, is the same as the catchability coefficient when the season is closed, $q^{closed}_j q^1_{ajm}$. This allows us to recover an intermediate catchability coefficient targeting *j* species and using *m* mode, $\tilde{q}^1_{ajm}$,

$$\tilde{q}^1_{ajm} = \frac{\left(\tilde{S}_{jm} - 1\right) q^{closed}_j q^1_{ajm} + q^1_{ajm}}{\tilde{S}_{jm}} = \left[\frac{\left(\tilde{S}_{jm} - 1\right) q^{closed}_{jm} + 1}{\tilde{S}_{jm}}\right] q^1_{ajm}.$$

However, since the new cost is added to purchase the TR permits in species *j*, the share of targeting species *j* ($\tilde{S}_{jm}$) will be decreased. Finally, under the TR program, new catchability coefficient will be written

$$q^{1TR}_{ajm} = \tilde{S}^{TR}_{jm} \cdot \tilde{q}^1_{ajm} + \left(1 - \tilde{S}^{TR}_{jm}\right) q^{closed}_{jm} q^1_{ajm},$$

[20] Values of the variables with tilde such as $\tilde{S}_{jm}$ will be given by the estimated demand model and they do not exist in the GBFSM as of October 2006.

where $\tilde{S}_{jm}^{TR}$ is the share of mode *m* recreational trips targeting species *j* under TR system. If the TR program is implemented only for the red snapper fishery, $\tilde{S}_{jm}^{TR}$, *j*=red snapper, will decrease and $\tilde{S}_{jm}^{TR}$, *j*=other species, will increase because of both the substitution effect and the price effect. This also indicates that the catchability coefficient of the red snapper fishery under the TR program will decrease with different magnitudes across modes but that of other species will increase. By providing the new set of catchability coefficients with consistent way of the current GBFSM, the TR policy will be interconnected with the simulation model and be compared with other policies.

Simulation Results from the TR Submodel

In this section, we explore the impacts of the TR policy to reduce fishing pressure in the GRS fishery. The results in this section are preliminary and partial, based only on the TR submodel. Therefore the results that are presented in this section are obtained only by using the subroutine of the TR policy for a single period. In the next main section of this chapter, we present results from the model. We can, however, use these results to look at the consequences of a TR program on the head, charter, and private boats because of our allowance for the mode-specific demand. In addition, the impacts can be analyzed by month. Specifically, we examine the market clearing price of the TR which makes the recreational harvests exactly binding to the current TAC. We then simulate the model with various TAC settings. We also carry out sensitivity analyses of policies for a variety of commercial net benefits to find out how much transfer will be made between recreational and commercial sectors.

Recreational Market

In table 5.1 we present the single-period simulation results supposing trading between the recreational and commercial sectors is not allowed. The market clearing price of the recreational per-day TR (P_{TR}) would be \$12.83 per day and the substitution rate would be 0.094. This means that recreational anglers should pay \$12.83 to purchase a unit of day-based TR and about 9.4% of anglers who used to target the red snapper fishery will substitute their targets with other fisheries to achieve the current goal of TAC (2.57 million lbs)[21]. The market clearing price of the day-based TR can be converted to fish-based and pound-based TRs using the average catch rate and pound per fish simulated by the GBFSM, assuming, as we have discussed above, that these rates do not change in response to the introduction of the TR program. The market clearing price of the fish-based TR would be \$5.02 per fish and on a pound-based TR would be \$1.34 per pound. We also measure an efficiency benefit of the TR program using the per-day consumer surplus as seen in figure 5.3. There would be \$0.4 million benefit to the head boat sector, \$3.3 million to the charter sector, and \$8.6 million to the anglers who fish using private boats. The increase in the total surplus under the TR program would be over \$12 million dollars.

[21] The TAC of the western Gulf states is assumed to be 2.57 million lbs. based on 2001 landings.

TABLE 5.1

TR Permit Price, Substitution Rate, and Benefit of TR Program

	Price per trip	Price per fish	Price per pound	Substitution Rate
Price & SR	$12.83	$5.02	$1.34	9.4%
	Head	Charter	Private	Total
Benefit	$428,212	$3,284,816	$8,628,343	$12,341,371

Figure 5.6 reports the predicted impact on trips of the $12.83 cost equally imposed on all modes, as well as a percentage declines for each mode (in parentheses). Note that the percentage loss in trips over the period is highest among private boat anglers, as one might expect because their travel cost is lowest. The additional cost of $12.83 to purchase the TR is predicted to reduce by about 28% of the number of private boat trips. Charter boat anglers also reduce their trips by about 14%, though their response is not as substantial as for the other modes.

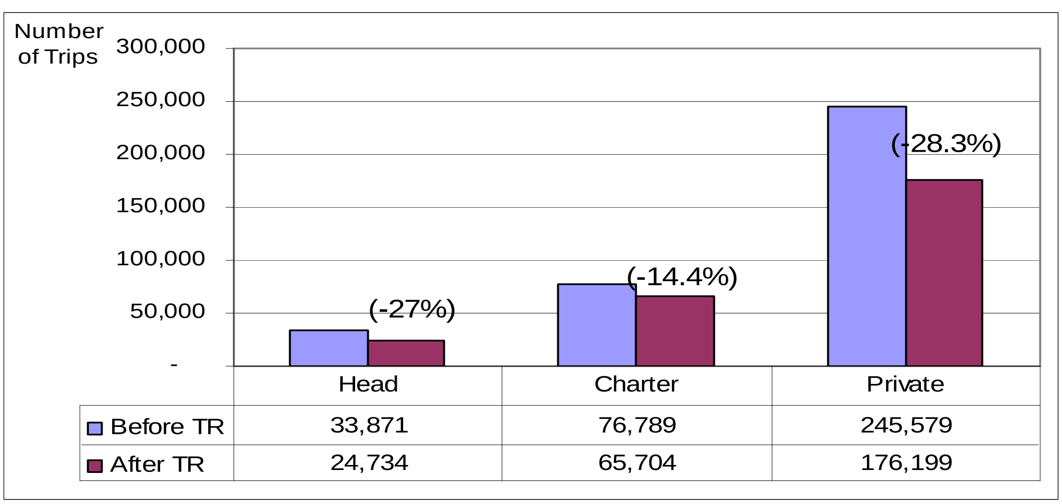

FIGURE 5.6

The Predicted Number of Recreational Trips in GRS Fishery with the TR Program

The predicted number of recreational trips in a month under the TR program is shown in figure 5.7. Spring season from March to June is most preferable season but after the TR program is implemented the trips are distributed over all year with fewer trips in January and February. Notice that the trip demand in the current closure season is not trivial; allowing anglers to go fishing during the current closed season will create substantial welfare gains.

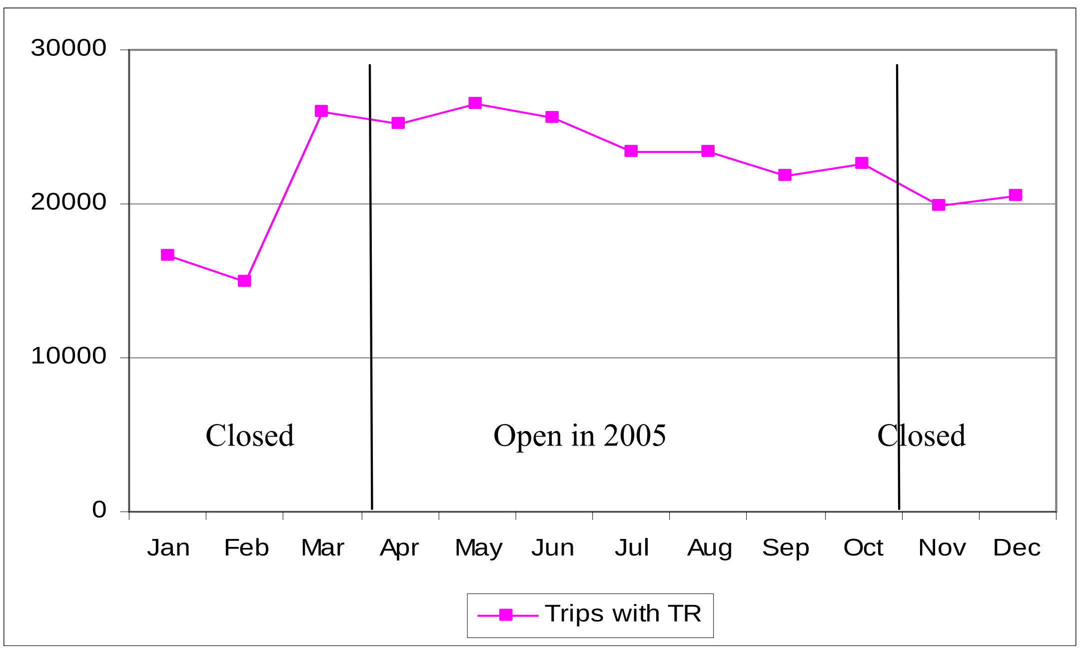

FIGURE 5.7

The Predicted Number of Monthly Trips in GRS Fishery under the TR Program

Table 5.2 shows the quantitative comparison under the different percentage declines of the TAC up to 50%. As the TAC is set to decrease, anglers will pay more to purchase the TR permits and will increase a degree of substitution of red snapper targeting trips away to other species. Our model predicts that a fifty percent decline of the TAC will require an angler to pay $43.4 to purchase a unit of day-based TR and 32% of anglers will change their targets to other species. Distributional impacts are also shown across fishing modes. The private boat sector would be most affected and the charter boat sector would be least affected. Also note that we predict substantial substitution to other species as the TAC is reduced and the TR price increase.

TABLE 5.2

Price of TR, Substitution Rate, and Harvests in Pound for Declines of TAC

% decline of TAC	Price of TR (per trip)	Substitution Rate	Head (lbs)	Charter (lbs)	Private (lbs)	TAC =Total Harvest
0%	$12.83	0.09	351,210	689,789	1,529,031	2,570,030
-10%	$17.55	0.13	312,257	650,102	1,350,667	2,313,027
-20%	$22.81	0.17	273,553	607,722	1,174,748	2,056,024
-30%	$28.74	0.21	235,170	562,112	1,001,739	1,799,021
-40%	$35.51	0.26	197,210	512,541	832,267	1,542,018
-50%	$43.42	0.32	159,824	457,979	667,212	1,285,015

Market for Commercial and Recreational Sectors

We now consider the TR program of the commercial sector as well as the recreational sector of the GRS fishery. The sales price of red snapper from the commercial landings can be predicted based on the 2001 commercial revenue and landings from the reef-fish logbook data provided by Waters in National Marine Fishery Service and they are deflated to 1997 dollars using the GDP index. However, cost data of commercial reef-fish vessels are rarely found. Waters (1996) reported some cost data for commercial vessels with vertical lines and bottom longlines based on the 1993 reef fish survey in the Gulf of Mexico. The high volume boats which have endorsements for the 2000 pound trip limit and are regarded as the major commercial vessels to catch red snapper are used to predict the per- pound marginal cost (MC). Cost data are also inflated to 1997 dollars. A sensitivity analysis is conducted under various price flexibility and per-pound MC settings of the commercial vessels.

In this section, the equilibrium price is approximated using a two-step process. First the commercial profit per day is calculated, giving a reservation for that sector's demand for the TR. Then the change in the price for red snapper is calculated using the assumed price flexibility (either from Park 1996 or sensitivity analysis as discussed below). With this new red snapper price, a new price for the TR is set based on the average profit per day for commercial vessels. Finally, the associated demand by the recreational sector is calculated. This will introduce approximation errors because the final TR price does not completely clear the market, though the magnitude of the error is directly related to the slope of the commercial red snapper demand curve. Since the demand curve used here is quite elastic, the magnitude of this error is probably inconsequential.

Table 5.3 presents how many pounds will be traded from the recreational sector to the commercial sector when transfer between two sectors is allowed as shown in figure 5.5. If the MC of commercial vessels is low at \$0.62/lbs, about 97 thousand pounds will be traded from the recreational sector to commercial sector. As the price flexibility becomes high, the amount of transfer decreases. This also indicates that if the commercial TR demand curve becomes less elastic, the commercial sector will demand fewer TR permits. On the other hand if the MC is high at $1.85/lbs, the recreational sector will purchase TR permits assigned to the commercial sector. Clearly, the simulation results are quite sensitive to the actual profits being achieved by the commercial sector.

TABLE 5.3

The Amount of Transfer from the Recreational Sector to the Commercial Sector Under Different Price Flexibility and Per-Pound Marginal Costs

Marginal Cost	Price Flexibility			
($/lbs)	-0.0341	-0.0682	-0.1705	-0.341
$0.62	45,507 lbs	45,192 lbs	44,247 lbs	42,668 lbs
$1.85	-260,258 lbs	-259,801 lbs	-258,432 lbs	-256,152 lbs

Note: Positive values indicate recreational sector sells and negative values indicate commercial sector sells.

Table 5.4 presents the effect of the TR program on the catchability coefficients under the TR program. With the TR program implemented only in red snapper, catchability coefficients of red snapper will decrease but those of other fisheries will increase due to the substitution effect. These new coefficients will be sent to the main GBFSM and will be used to simulate biological impacts of the TR program.

TABLE 5.4

Changes in the Catchability Coefficients with the TR Program

		Head	Charter	Private
Without TR	Red snapper & Other fishery	1	1	1
With TR	Red snapper	0.908	0.944	0.900
With TR	Other fishery	1.029	1.016	1.013

A 10-Year Period Simulation Incorporated with the GBFSM

We now use a 10-year simulation period to assess the long-term effects of a TR program and compare policy scenarios. Results in this section are computed after the subroutine of the TR policy is linked to the main GBFSM through a year loop. Biological effects are incorporated by taking the catchability coefficients and the number of trips for all fisheries back to the GBFSM. However, the results are limited to the western Gulf because the main GBFSM is calibrated for four western Gulf states (Texas, Louisiana, Mississippi, and Alabama).

Recreational Market

Table 5.5 presents the simulated number of trips and pounds landed under only recreational TR program over a 10-year period. The first row of the table presents the simulated values of the base year of 2001.[22] The reason why 2001 is used as a base year is that the biological model tuned using 2001 data although price and cost are in 1997 dollars. As the TR program is implemented only in the recreational sector, total pounds landed of red snapper shown in the last column would decrease but they do not match the TAC. This discrepancy arises because the simple actual catch model in GBFSM is more complicated than the linear model that is used to establish the changes in the catchability coefficients discussed above.

TABLE 5.5

The Number of Trips and Pounds Landing over a 10-Year Period

Under Only Recreational TR Program

		The number of Trips for all fisheries			Pounds landing for red snapper			
Year	TAC	Head	Charter	Private	Head	Charter	Private	Total
Base	2570030	65,750	367,329	1,157,812	414,226	667,071	1,488,733	2,570,030
1	2570030	65,883	399,096	1,249,307	413,737	723,796	1,352,885	2,490,418
2	2570030	65,843	392,511	1,241,416	418,780	715,951	1,360,445	2,495,176
3	2570030	65,727	392,253	1,245,095	419,848	718,523	1,373,437	2,511,808
4	2570030	65,591	391,969	1,249,467	420,101	719,317	1,385,991	2,525,409
5	2570030	65,454	391,523	1,253,618	419,688	719,194	1,395,605	2,534,487
6	2570030	65,319	390,951	1,257,553	419,035	718,523	1,402,716	2,540,274
7	2570030	65,186	390,252	1,261,222	418,305	717,403	1,408,185	2,543,893
8	2570030	65,058	389,420	1,264,564	417,588	716,004	1,412,902	2,546,494
9	2570030	64,935	388,450	1,267,491	416,911	714,369	1,417,044	2,548,324
10	2570030	64,819	387,332	1,269,965	416,298	712,552	1,420,613	2,549,463

[22] The reason 2001 was used as the base year is that the biological model was tuned using 2001 data. Prices and costs are in 1997 dollars.

As can be seen, the total pounds landed is moving toward the TAC over time and should, after many years, reach the actual TAC introduced in the model. Pounds landed by head and charter boats are predicted to increase. This indicates that anglers desiring for-hire trips are less willing to pay the additional cost and would buy permits from private boat users. The number of trips of all fisheries will increase for all modes in the first year of the TR program but will slightly decrease over the 10-year period.

Table 5.6 shows the simulated producer, consumer, and total surpluses over a 10-year period under the only recreational TR program. The producer surplus of the for-hire sector of head and charter boats is calculated by the revenues subtracted only by variable costs. After the TR program is implemented the total surplus for the first year is greater than that of the base year. The most surplus gains are generated in the producer surplus of the charter boat sector. The consumer surplus increases for the charter anglers but decreases for the private boat anglers.

TABLE 5.6

Producer, Consumer, and Total Surpluses over a 10-Year Period

Under Only Recreational TR Program

Year	Head PS	Charter PS	Head CS	Charter CS	Private CS	Total Surplus
Base	1,780,835	17,591,932	1,541,972	9,417,867	23,525,769	53,858,375
1	1,784,427	19,113,293	1,544,830	9,574,310	23,425,854	55,141,396
2	1,783,345	18,797,918	1,545,092	9,426,945	23,406,361	54,802,952
3	1,783,921	18,793,986	1,545,050	9,424,147	23,408,584	54,803,079
4	1,783,886	18,796,666	1,545,035	9,425,471	23,409,595	54,806,968
5	1,783,859	18,797,107	1,545,027	9,425,723	23,410,164	54,808,060
6	1,783,843	18,797,305	1,545,023	9,425,842	23,410,436	54,808,589
7	1,783,836	18,797,451	1,545,021	9,425,922	23,410,553	54,808,889
8	1,783,834	18,797,539	1,545,020	9,425,968	23,410,626	54,809,076
9	1,783,833	18,797,598	1,545,019	9,425,998	23,410,682	54,809,205
10	1,783,831	18,797,631	1,545,018	9,426,016	23,410,721	54,809,287

Note: PS= Producer Surplus and CS=Consumer Surplus

Market for Recreational and Commercial Sectors

We now consider the case in which the TR program is now implemented in both recreational and commercial sectors. Table 5.7 shows the producer, consumer, and total surpluses over a 10-year period when the TR program is implemented in both recreational and commercial sectors and they are allowed to trade their rights. The table includes two subtables with different price flexibilities. In this case, the total surplus under the TR program would become smaller than that in the base year although the surplus loss will declines with the greater price flexibility. The decline of total surplus is due to the fact that producer surplus in the for-hire recreational sector is a linear function of the number of trips taken by that sector. However that surplus is not reflected in demand for TRs.[23]

TABLE 5.7

Producer, Consumer, and Total Surpluses over a 10-Year Period

Under Both Recreational and Commercial TR Programs

1) With -0.0341 of Price Flexibility (Park 1996)

Year	Head PS	Charter PS	Head CS	Charter CS	Private CS	Total Surplus
Base	1,780,835	17,591,932	1,541,972	9,417,867	23,525,769	53,858,375
1	1,763,370	19,087,158	1,514,909	9,224,565	22,866,189	54,456,191
2	1,767,334	18,790,796	1,504,140	9,204,632	22,788,324	54,055,226
3	1,758,581	18,766,709	1,494,266	9,188,193	22,741,414	53,949,163
4	1,750,109	18,745,905	1,485,007	9,168,344	22,704,254	53,853,619
5	1,741,884	18,715,889	1,476,270	9,145,231	22,673,266	53,752,540
6	1,733,912	18,677,533	1,468,035	9,118,583	22,645,873	53,643,936
7	1,726,222	18,630,559	1,460,474	9,088,321	22,622,285	53,527,861
8	1,718,955	18,574,543	1,453,726	9,054,136	22,602,382	53,403,742
9	1,712,220	18,508,601	1,448,027	9,016,441	22,586,655	53,271,944
10	1,706,220	18,433,273	1,444,905	8,973,140	22,581,064	53,138,602

[23] In addition, the estimated total surplus is an incomplete measure because commercial sector's producer surplus is not included. The commercial sector's producer surplus is not accessible as of November 2006 because commercial TAC is not linked to the main GBFSM.

TABLE 5.7 Continued

2) With -0.341 of Price Flexibility (10 times larger than Park's)

Year	Head PS	Charter PS	Head CS	Charter CS	Private CS	Total Surplus
Base	1,780,835	17,591,932	1,541,972	9,417,867	23,525,769	53,858,375
1	1,764,685	19,088,804	1,516,759	9,227,578	22,900,774	54,498,600
2	1,768,324	18,791,233	1,506,719	9,209,089	22,835,826	54,111,191
3	1,759,990	18,767,977	1,497,488	9,193,838	22,800,684	54,019,977
4	1,751,877	18,747,664	1,488,870	9,175,226	22,775,130	53,938,767
5	1,744,015	18,718,270	1,480,763	9,153,406	22,755,506	53,851,960
6	1,736,405	18,680,710	1,473,143	9,128,113	22,739,193	53,757,564
7	1,729,071	18,634,730	1,466,163	9,099,254	22,726,100	53,655,318
8	1,722,146	18,579,925	1,459,937	9,066,500	22,715,812	53,544,320
9	1,715,719	18,515,445	1,454,676	9,030,207	22,708,413	53,424,460
10	1,709,980	18,441,778	1,451,680	8,988,308	22,707,315	53,299,061

Note: PS= Producer Surplus and CS=Consumer Surplus

Concluding Remarks

This chapter develops the theoretical foundation and the simulation submodel that will be used to conduct an economic analysis of the TR program. We elaborate in detail how the TR subprogram is introduced into GBFSM in order to simulate the policy's effectiveness in reducing overfishing. Some partial results taken from the submodel of the TR program are presented. Because the TR program allows anglers to go fishing throughout the year, an efficiency gain moving from the current closures to the TR program would be substantial.

CHAPTER VI

SUMMARY AND CONCLUSION

This dissertation contemplates how a transferable rights (TR) system could be designed for the use in a recreational fishery such as the Gulf red snapper fishery. Despite the increasing number of restrictions imposed on the Gulf's anglers the total estimated recreational harvests still regularly exceeds the TAC allocated to the recreational sector. In order to overcome the recent overfishing situation TR programs are being increasingly considered in the recreational fishery. The primary objective of this dissertation is to develop a conceptual framework and an empirical model to analyze the possible use of a TR program for the recreational fishery.

In chapter II, an overview of the conceptual framework was provided to investigate in more detail the issues of how a TR program might be implemented in the red-snapper recreational fishery. The existing regulations surrounding recreational fishery management were also reviewed. In addition, some lessons from hunting programs and other applications of TRs were introduced to find out preferable institutional schemes for the recreational TR program. We have summarized the issues at stake and present the advantages and disadvantages of alternative solutions.

Chapter III presented a representative angler's utility maximization problem. Analytical models of different units of measurement of TRs such as fish, day, and pounds were developed and comparative statics of decision variables which affect the utility was carried out with respect to the permit price. However we could not confirm which unit of measurement would maximize a representative angler's utility the most.

The objective of chapter IV is to estimate an empirically based recreation demand that incorporates TR permit demand. Four model specifications were used to find a better model to estimate the recreational trip demand. We then examined a daily access fee-based policy as an approximate price instrument of TR program. We find that a fee can be very effective in reducing recreational fishing demand in the Gulf of Mexico. However, we also point out a price instrument such as a fee and TRs to rationing would lead to distributional consequences across modes. Our results indicate that a user fee would have much greater impacts on low income groups, than on higher ones and would affect low-cost fishing modes much more than it would modes that are relatively expensive.

The main purpose of chapter V is to develop a conceptual framework of a simulation submodel of the TR program. The assumptions that are used to build the individual and aggregate TR demand were carefully described. We provide a conceptual foundation to explain how the market clearing price of the TR is determined and how the TR program works to allocate permits not only within one sector but also between recreational and commercial sectors. Because the main GBFSM is under development, only partial and preliminary results taken from the submodel of the TR program are presented. Although anglers would need to pay additionally to purchase the TR permits, we find that an efficiency gain moving from the current closures to the TR program would be substantial.

This dissertation initially reviewed the critical issues in the implementation of the TR program in a recreational fishery. Although the use of TRs in recreational fisheries is a relatively new idea, we believe that it is an idea that has a great deal of merit and the institutional barriers are not insurmountable. We think that trading being carried out on the Internet or electronic systems with relatively low transaction costs would be the key to reduce these barriers. Should transferable permits become legal, they offer the potential to increase overall economic efficiency in both commercial and recreational fisheries by making it possible for the fishermen who value the resource the most to harvest the fish. We find that the trip demand in the current closed season is not trivial so that the TR program, which makes restricted entry unnecessary, would create a considerable benefit. As with other price instruments, the TR program will more significantly affect the poorest (or low-cost) user groups.

As is often the case with newly promising policies, there are caveats in this dissertation. First, this dissertation could not show which unit of measurement for the rights is preferable in terms of maximizing anglers' utility. We propose the day-based permit because it is a relative advantage in terms of controlling and enforcement of the use of the TR permits. However, more precise investigation should be provided theoretically and empirically to answer this question. Second, associated with the first caveat, this dissertation assumes constant the catch rate and average pound per fish when converting the impact of a day-based permit into quantity of fish harvested. This assumption is problematic. Inevitably, if a day-based TR program were introduced catch rates would increase as anglers try to get "more for their money" and more experienced anglers tend to purchase the rights. Hence, this assumption would lead to biased results because a change in price would affect the number of fish caught or landed. Estimating the extent to which these rates would change endogenously, is a conceptual and empirical challenge that we have not attempted to resolve in this work. The third caveat is that the simulation results are partial and preliminary only for the western Gulf of Mexico, and an equilibrium price for both commercial and recreational markets is also approximated using a two-step process. A complete analysis could be conducted following the general framework and submodel that this dissertation already provided.

Suggestions for the future research are closely associated with further simulation analysis. Once a fully calibrated simulation model is accessible and the subroutine of the TR program is successfully linked to the main model, the TR program can be compared with a suite of other policy alternatives in terms of economic and biological aspects.

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APPENDIX 1

MATHEMATICAL PROOF FOR CHAPTER III

First, define $A = (\alpha_l \cdot k + \alpha_t) > 0$, $B = 2\beta_l \cdot k^2 + 2\beta_t < 0$, and $C = (c - \alpha_d) < 0$. The signs of *A*, *B*, and *C* can be derived from the optimal solutions for decision variables. The condition where total amounts of fish landed are same leads to the price relationship between P_f and P_d.

$$d_f^* \cdot l_f^* = d_f^* \cdot l_f^* \text{ or } d_f^* \cdot (\cancel{k} \cdot t_f^*) = d_d^* \cdot (\cancel{k} \cdot t_d^*)$$
$$\left(\frac{C \cdot B - P_f \cdot k \cdot A}{2\beta_d \cdot B - P_f^2 \cdot k^2}\right)\left(\frac{P_f \cdot k \cdot C - 2\beta_d \cdot A}{2\beta_d \cdot B - P_f^2 \cdot k^2}\right) = \left(\frac{C + P_d}{2\beta_d}\right)\left(\frac{-A}{B}\right)$$
$$\frac{(C \cdot B - P_f \cdot k \cdot A) \cdot (P_f \cdot k \cdot C - 2\beta_d \cdot A)}{(2\beta_d \cdot B - P_f^2 \cdot k^2)^2} = \frac{-A(C + P_d)}{2\beta_d \cdot B}$$

The price of day-based permit which makes total amount of fish landed between two unit alternatives equal becomes:

$$P_d = \frac{-2\beta_d \cdot B \cdot (C \cdot B - P_f \cdot k \cdot A) \cdot (P_f \cdot k \cdot C - 2\beta_d \cdot A)}{A \cdot (2\beta_d \cdot B - P_f^2 \cdot k^2)^2} - C. \qquad \text{[A-1]}$$

Note that l_d^* and t_d^* do not include P_d. The signs of differences between l_f^* and l_d^*, and between t_f^* and t_d^* are demonstrated in [A-2] and [A-3].

$$D_l = l_f^* - l_d^* = \frac{P_f \cdot k^2 \cdot C - 2\beta_d \cdot k \cdot A}{2\beta_d \cdot B - P_f^2 \cdot k^2} - \frac{-k \cdot A}{B} \qquad \text{[A-2]}$$

$$=\frac{B(P_f\cdot k^2\cdot C-2\beta_d\cdot k\cdot A)+k\cdot A(2\beta_d\cdot B-P_f^2\cdot k^2)}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}=\frac{B\cdot P_f\cdot k^2\cdot C-A\cdot P_f^2\cdot k^3}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}$$

$$=\frac{P_f\cdot k^2(B\cdot C-A\cdot P_f\cdot k)}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}=\frac{P_f\cdot k^2(B\cdot C-A\cdot P_f\cdot k)}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}=\frac{\underset{+}{P_f}\cdot\underset{+}{k^2}}{\underset{-}{B}}\cdot\underset{+}{d_f^*}<0$$

$$D_t=t_f^*-t_d^*=\frac{P_f\cdot k\cdot C-2\beta_d\cdot A}{2\beta_d\cdot B-P_f^2\cdot k^2}-\frac{-A}{B}\tag{A-3}$$

$$=\frac{B(P_f\cdot k\cdot C-2\beta_d\cdot A)+A(2\beta_d\cdot B-P_f^2\cdot k^2)}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}$$

$$=\frac{B\cdot P_f\cdot k\cdot C-A\cdot P_f^2\cdot k^2}{B\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}=\frac{p_f\cdot k(B\cdot C-A\cdot p_f\cdot k)}{B\cdot(2\beta_d\cdot B-p_f^2\cdot k^2)}$$

$$=\frac{\underset{+}{P_f}\cdot\underset{+}{k}}{\underset{-}{B}}\cdot\underset{+}{d_f^*}<0$$

$$D_d=d_f^*-d_d^*\tag{A-4}$$

$$=\frac{C\cdot B-P_f\cdot k\cdot A}{2\beta_d\cdot B-P_f^2\cdot k^2}-\left\{\frac{C}{2\beta_d}+\frac{1}{2\beta_d}\left(\frac{-2\beta_d\cdot B\cdot(C\cdot B-P_f\cdot k\cdot A)\cdot(P_f\cdot k\cdot C-2\beta_d\cdot A)}{A\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)^2}-C\right)\right\}$$

$$=\frac{C\cdot B-P_f\cdot k\cdot A}{2\beta_d\cdot B-P_f^2\cdot k^2}-\left\{\cancel{\frac{C}{2\beta_d}}-\cancel{\frac{C}{2\beta_d}}+\frac{1}{\cancel{2\beta_d}}\left(\frac{-\cancel{2\beta_d}\cdot B\cdot(C\cdot B-P_f\cdot k\cdot A)\cdot(P_f\cdot k\cdot C-2\beta_d\cdot A)}{A\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)^2}\right)\right\}$$

$$=\frac{C\cdot B-P_f\cdot k\cdot A}{2\beta_d\cdot B-P_f^2\cdot k^2}-\left(\frac{-B\cdot(C\cdot B-P_f\cdot k\cdot A)\cdot(P_f\cdot k\cdot C-2\beta_d\cdot A)}{A\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)^2}\right)$$

$$=\left(\frac{C\cdot B-P_f\cdot k\cdot A}{2\beta_d\cdot B-P_f^2\cdot k^2}\right)\left(1-\frac{-B\cdot(P_f\cdot k\cdot C-2\beta_d\cdot A)}{A\cdot(2\beta_d\cdot B-P_f^2\cdot k^2)}\right)=d_f^*(1-\frac{t_f^*}{t_d^*})>0$$

Because t_f^* is less than t_d^* as shown in equation [A-3], the sign of $\frac{t_f^*}{t_d^*}$ should be less than 1. Consequently, D_d should be positive. Finally, the utility difference between two unit alternatives can be written

$$D_U = u_f - u_d \qquad \text{[A-5]}$$

$$= \left\{ \gamma + \alpha_d d_f^* + \beta_d d_f^{*2} + (\alpha_l k + \alpha_t) \cdot t_f^* + (\beta_l k^2 + \beta_t) \cdot t_f^{*2} + (\alpha_s \underline{s} + \beta_s \underline{s}^2) \right\}$$

$$- \left\{ \gamma + \alpha_d d_d^* + \beta_d d_d^{*2} + (\alpha_l k + \alpha_t) \cdot t_d^* + (\beta_l k^2 + \beta_t) \cdot t_d^{*2} + (\alpha_s \underline{s} + \beta_s \underline{s}^2) \right\}$$

$$= \underset{+}{\alpha_d} \underset{+}{(d_f^* - d_d^*)} + \underset{-}{\beta_d} \underset{+}{(d_f^{*2} - d_d^{*2})} + \underset{+}{(\alpha_l k + \alpha_t)} \cdot \underset{-}{(t_f^* - t_d^*)} + \underset{-}{(\beta_l k^2 + \beta_t)} \cdot \underset{-}{(t_f^{*2} - t_d^{*2})}.$$

The sign of D_U is ambiguous.

APPENDIX 2

ESTIMATION RESULTS OF HEDONIC WAGE FUNCTION

Dependent Variable: HR_WAGE

Method: Least Squares

Included observations: 1663

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.634138	4.656740	0.136176	0.8917
AGE	0.779103	0.203294	3.832390	0.0001
AGE2	-0.007057	0.002479	-2.846805	0.0045
WHITE	1.654453	1.504920	1.099363	0.2718
MALE	4.111645	1.324988	3.103157	0.0019
DWAGE	-11.63140	0.800576	-14.52878	0.0000

R-squared	0.159936	Mean dependent var	18.19456
Adjusted R-squared	0.157401	S.D. dependent var	17.23988
S.E. of regression	15.82504	Akaike info criterion	8.364665
Sum squared resid	414965.4	Schwarz criterion	8.384207
Log likelihood	-6949.219	F-statistic	63.09376
Durbin-Watson stat	0.089204	Prob(F-statistic)	0.000000

Note: HR_WAGE=hourly wage.

AGE=respondents' age.

AGE2=Age squared.

WHITE=an ethnical dummy variable if white=1, otherwise=0.

MALE= A gender dummy variable if Male=1, otherwise=0

Dwage is a dummy variable if hourly wage = 1 , salary/2000=0.

The estimator of Dwage is highly significant and negative.

VITA

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PUBLICATION

Kim, Hwa Nyeon, W. D. Shaw, and R. T. Woodward. "The Distributional Impacts of Recreational Fees: A Discrete Choice Model with Incomplete Data." Forthcoming (November 2007) *Land Economics*.