Tradable Effort Permits: A Case Study of the Florida Spiny Lobster Trap Certificate Program

Sherry L. Larkin and J. Walter Milon, University of Florida

Abstract. The Florida spiny lobster trap certificate program (TCP) is one of the oldest U.S. fisheries programs involving tradable effort permits. Under the TCP, fishers must own a certificate (and pay an associated annual fee) for each trap used. The program was created in 1992 to address overcapitalization amid growing social conflict in the fishery due to open-access regulation. Consequently, the total number of certificates (effort) is periodically reduced. However, no terminal effort level was designated so an intense debate has developed over future reductions. A bioeconomic analysis revealed that the current effort level (which is 34% below the initial level) remains approximately three times higher than even the most liberal estimate of "optimal" effort (i.e., effort that would generate the maximum economic yield). An analysis of the certificate market also indicated that prices have not approached levels reflecting the net present value of rents at the optimal effort level. These results suggest that existing regulations have failed to achieve the potentially large economic surplus that could result from optimal management. Prior to the implementation of similar programs, resource managers may want to consider lessons learned from the TCP. First, the social and political forces created by granting harvest rights tend to accentuate the problems of contracting among heterogeneous participants. Second, the fee schedule and budgetary issues can affect the structure and performance of the transfer market. Lastly, an elusive social surplus may not be a sufficient reward to overcome social, economic, and regulatory impediments to economically optimal regulation.

Keywords: Effort permits, fisheries management, Florida lobster fishery, trap certificates, spiny lobster

1. INTRODUCTION

The state of Florida has managed the commercial spiny lobster trap fishery using a tradable effort permit program since 1992. Under this input control program, individuals own shares of a restricted input, but output is unregulated. This type of program can be contrasted with an output control program, such as individual transferable quotas (ITQs) where individuals own shares of a restricted output. The commonality between these programs is that they both allow shares to be bought or sold. The transfer of shares essentially generates a private market for effort or harvest rights, which can allow for efficiency and profitability gains in the fishery (Squires et al. 1995). Preliminary results from transferable share programs show favorable results as the fisheries move toward more efficient production (National Research Council 1999). Consequently, an evaluation of the program in Florida may reveal important information about the effectiveness of one of the first transferable effort control programs for a commercial U.S. fishery.

The Florida spiny lobster (*Panulirus argus*) fishery is characterized by numerous regulations that are intended to protect the stock and standardize effort, including minimum size, seasons, a prohibition on the harvest of gravid females, and trap size and construction limits. These regulations could not, however, prevent the development of open-access resource use problems in the 1980s. From 1960 to 1990 the fishery experienced a significant increase in the number of traps while landings remained relatively stable. Thus, even though the stock appeared robust to the increased effort (as high catch levels continued), the additional effort caused several other concerns about the sustainability of the industry. In particular, the Florida Legislature observed that:

> Due to rapid growth, the spiny lobster fishery is experiencing increased congestion and conflict on the water, excessive mortality of undersized lobsters, a declining yield per trap, and public concern over petroleum and debris pollution from existing traps (Florida Statute 370.142(1)).

In response, the total number of traps was regulated in 1992 with implementation of the Trap Certificate Program (TCP). The mandated goal of the TCP was essentially an economic one, that is, "to stabilize the fishery by reducing the total number of traps, which should increase the yield per trap and therefore maintain or increase overall catch levels" (Florida Statute 370.142(1)). Note that biological concerns, such as would be addressed through catch reduction requirements, were not cited. The TCP ended an era of open-access

management of the spiny lobster fishery in Florida by establishing a cap on total effort (i.e., traps).

Under the TCP, licensed commercial fishers own certificates, which allow the use of an equivalent number of traps. The initial certificate allocation was based on reported trap use in the preceding 3-year period. The initial total effort level was below the historical high since some individuals were not able to verify their claims and a maximum was placed on the number allocated to any one individual. Fishers pay an annual certificate fee ($1.00 in 1999-2000) and, in return, receive a tag for each certificate owned. The tags are attached to the traps and indicate the trap is legal for that season (tags are color-coded each season and stamped with a certificate number that can be used to identify the owner). Certificates are transferable, all or in part, among fishers provided they are exchanged for a "fair market value" and the applicable transfer fees are paid ($2 per certificate plus a 25% surcharge on original transfers to non-family members). In addition, no one person, firm, corporation, or other business entity may control, directly or indirectly, more than 1.5% of the total number of certificates available in any license year (Florida Statute 370.142(2)a.2).

The total number of certificates available (i.e., the total effort level) is determined by the Florida Fish and Wildlife Conservation Commission. The Commission was delegated the authority to reduce the total number of certificates by reducing each individuals holdings by no more than 10% per year. The commission is not required to authorize any reductions, but cannot issue new certificates (Florida Statute 370.142(3)). Since the total number of certificates can never increase under the current legislation, the implementation of the TCP was considered a restricted entry program. Consequently, the legislation explicitly allows for the assessment of "an equitable rent per trap" payable by certificate holders as "partial compensation to the state for the enhanced access to its natural resources" (Florida Statutes 370.142(2)a.1). To date, such a fee has not been assessed.

The purpose of this study was two-fold. The first goal was to determine the total number of traps that would maximize the net economic benefits in the commercial fishery and, thus, test the hypothesis that previous certificate reductions have achieved an economically optimal and sustainable number of traps in the fishery. This was accomplished by estimating several surplus-production and harvest-cost models for use in an integrated bioeconomic analysis. The second goal was to evaluate the market for trap certificates (including observed prices and transfers), changes in the number of fishers, and the fiscal self-sufficiency of the program. The conclusion addresses the future management of the fishery and how observed unintended consequences may be avoided in similar programs.

2. DATA

Catch and effort data, as well as records of certificate transactions and program net revenues since the inception of the TCP, were obtained from the State of Florida. The catch and effort data consist of annual landings and trap use from 1960 to 1997 and are shown in Figure 1. This is the data used to estimate the marginal productivity curves.

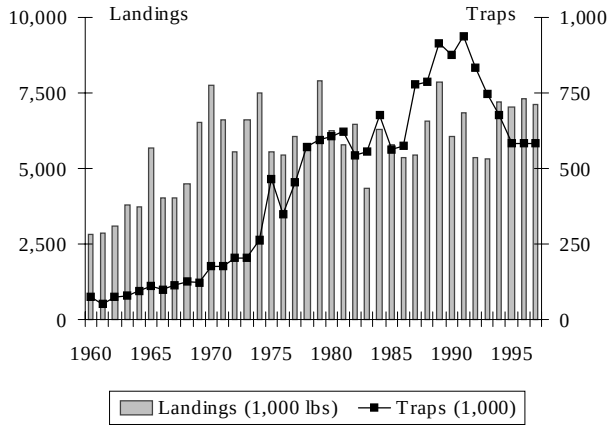

Figure 1. Commercial Landings and Traps in Florida

Landings are the quantity purchased (total pounds whole weight) by licensed wholesale dealers and are assumed to equal total commercial catch (C). This is a reasonable assumption since traps only hold adult lobsters and fishers pull the traps every few days (Milon et al. 1998). These landings exclude harvests by the recreational sector.[1]

Fishing effort (E) is the total number of traps operated by commercial fishermen. Wooden slat traps have been the primary commercial gear type since the late 1950s (Labisky et al. 1980) and they currently account for approximately 95% of commercial landings (Hunt et al. 1998). It is implicitly assumed that fishing practices have

[1] Excluding recreational landings was necessary since statistics are not available for the entire period and effort is measured differently than in the commercial sector. Omitting the recreational landings will not affect the shape of the production function at recent effort levels since these landings have remained a relatively constant share of total landings since data collection began in 1991 (Hunt et al. 1998).

not changed over time and do not differ among fishers. These are valid assumptions given that trap size and construction have been regulated since 1965. In addition, fishing technology changes that may have increased the rate of harvest – which is accounted for in the cost information and biological coefficients – would not have affected resource availability and, therefore, estimation of a long-run surplus production function.

As shown in Figure 1, annual landings in Florida averaged approximately 3 million pounds in the early 1960s. Since 1975, however, landings have ranged from 4.3 to 7.8 million pounds, with no apparent trend. Total effort increased significantly from 1960 to 1992, from less than 100,000 to nearly one million traps. The dramatic increase in traps with relatively stable landings caused the catch per unit effort for the commercial trap fishery to decline approximately 80% during this period, from an average of nearly 50 pounds per trap to less than 8. Since 1992, when the TCP was implemented, the number of traps has been reduced to approximately 544,000 and average trap yields have increased above 13 pounds.

Cost data needed to estimate the marginal cost per trap was obtained during interviews conducted with a stratified sample of lobster fishers in the Florida Keys (Milon et al. 1999). Variable costs included trip costs (fuel, bait, groceries, ice, supplies, and labor payments), equipment leasing and repair, and maintenance expenses incurred during 1996. These costs averaged $16,366 exclusive of labor. Labor payments equaled $12,950 assuming the captain and crew were paid the minimum wage ($5.15 per hour). Using the minimum wage was necessary since preliminary surveys indicated a variety of compensation methods were used and this information was a sensitive issue that many did not wish to discuss. Basing the labor costs on the minimum wage provides an estimate of the minimum opportunity cost associated with work hours expended in this fishery.[2] Fixed costs averaged $21,238 annually and included interest payments, docking fees, depreciation (vessels and gear), and licensing.

3. TRANSITION UNDER THE PROGRAM

Several criteria are used to measure and evaluate the market for trap certificates, including changes in the total number of certificates, concentration ratios, the number of participants, certificate transfers (i.e., number, volume, and price), and revenues and administrative costs from 1992 through 1998. For further detail and information, interested readers are referred to Milon et al. (1998).

3.1 Certificate Balance

Although each certificate allows the use of a single trap, certificates are categorized to identify different types of ownership:
(1) Type A-1: Certificates received from the initial allocation, an appeal, or through lotteries of abandoned certificates and have never been transferred.
(2) Type A-2: Certificates sold to members of the immediate family (i.e., parent, step-parent, child, step-child, sibling, or spouse) following the initial allocation.
(3) Type B: Type A-1 or A-2 certificates sold to individuals outside the immediate family.

A distinction is made between sales to individuals outside the immediate family and sales to family members since the latter transactions are not subject to the 25% surcharge fee and they are the last type of certificate affected by a reduction in the number of certificates. That is, if the number of traps to be reduced exceeds the number of unpaid certificates (which are reduced first), the first reductions apply to an individual's Type B certificates, then Type A-2, and last to Type A-1 certificates that have never been transferred.

The total number of certificates – and, therefore, the maximum number of legal traps in the commercial sector – has decreased since the initial allocation due to four mandated 10% reductions. The initial allocations in 1993 and subsequent allocations from appeals in 1994 totaled approximately 825,000 certificates. The number of certificates available by type during each fishing season along with the timing of the reduction (which occurred at the beginning of the season) are shown in Figure 2. Overall, the total number of certificates has declined 34% and the composition by certificate type has changed.

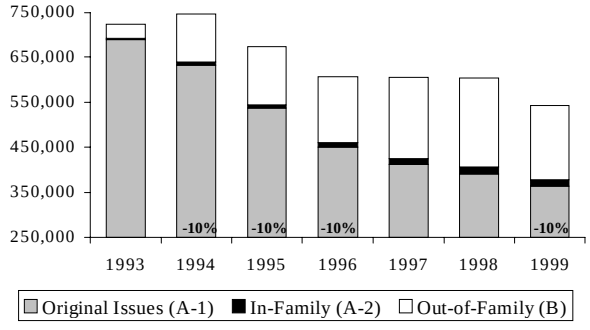

Figure 2. Number and Composition of Certificates

[2] Following most empirical fisheries studies, the resulting optimal rents are more accurately referred to as profits since the true opportunity costs cannot be measured (Anderson 1986).

Upon initial allocation, all certificates were of Type A-1. During the first year under the program, the percentage of Type A-1 certificates fell to 95% due to transfer activity. By the 1998-99 season, only 67% of the total number of certificates were of Type A-1. During that same time, the proportion of Type A-2 and Type B certificates increased from zero to 2.5% and 30.6%, respectively.

3.2 Concentration of Ownership

Differences in production costs are expected to change the concentration of certificate holdings under the TCP. Differences in production cost can result from differences in the captain's skill, vessel characteristics and operation, and/or efficiency of the crew. Theoretically, it is beneficial for a certificate holder to sell when the price offered is greater than their expected discounted stream of rents from the continued use of the certificate. Consequently, the least efficient firms will find it rational to leave the industry (although some may exit for non-economic reasons such as poor health).

There are many ways to measure the concentration of a market. One commonly used measure is the Concentration Ratio, which sums the market shares of the largest firms. In this paper the "market" refers to the total number of certificates available and "firms" are the individual certificate holders. Given the relatively large number of firms, these ratios are calculated with more firms than may be customary.

The concentration ratios indicate an increasing, although small, degree of concentration. For example, the 100 individuals who own the most certificates collectively accounted for 34% of the total in 1993 but 38% in 1999. In the commercial spiny lobster fishery, however, 100 individuals represented less than 5% of the total number of certificate holders in 1998. Although this ratio increased slightly, it is unclear whether the increase represents a continuing trend. In contrast, the concentration of certificate ownership by the largest 500 firms (representing 23% of all certificate holders) increased eight percentage points from 88% to 96%. It should be noted that the majority of individuals (61% or 1,310) held only the minimum number of certificates (i.e., six following the four reductions) and, therefore, may not be appropriately considered commercial harvesters. Given that these individuals are technically members of the commercial sector and are allowed to increase certificate holdings, they were retained in this analysis.

3.3 Participants and Firm Size

A total of 3,896 individuals have been involved in the TCP by owning certificates since its inception. The total number of certificate holders fell from 3,696 in 1993 to 2,158 in 1999, a decrease of 42%. Conversely, the size of the average operation increased during the TCP. From 1993 to 1999, the average number of certificates held increased from approximately 196 to 252 (28%). In addition, the maximum number of certificates held by any one individual increased from 3,674 to 5,631 (53%) during the period.

3.4 Certificate Transfers

Certificate transfers are only accepted by the state between August 1 and March 1, the fishing season. This limited transfer period allows for calculation of year-end balances, a reduction of certificates if mandated, and the preparation of invoices for the annual fee.

During the first full trading season (August 1, 1993 to March 31, 1994) over 12% of all certificates changed hands. During the following years, the proportion of certificates traded remained stable between 8% and 10% but fell to just 6% in 1998. Overall, at least 326,208 certificates were transferred between the 1993 and 1998 seasons. Type A-1 certificates transferred, as a percentage of the total, fell from 94% in 1994 to just 54% in 1998. Conversely, the proportion of Type B certificates transferred increased from 6% to 43%. The average number of A-2 certificates transferred was 573, which accounted for 0.5% to 2.2% of the total number of certificates traded. Since the first full trading season, the total number of certificates traded remained stable from 1995 through 1997, ranging from approximately 53,000 to 55,000 certificates annually. The total number of transfers declined approximately 35% in 1998, likely due to the 10% reduction planned for the end of the season.

It is also interesting to note the extent of trading activity between years. For example, 73 people traded in both the 1994 and 1995 seasons, 53 traded in 1995 and 1996, 43 traded in 1996 and 1997, and 62 traded in 1997 and 1998. Transacting in consecutive years may reflect one or more of the following:

(1) the adjustment of traps necessary to correct for imperfections in the original allocation of certificates;
(2) the adjustment in trap numbers necessary to attain the most profitable size fishing operation given the scale of remaining inputs (e.g., vessel size); and/or
(3) speculative activity in the market for certificates.

3.5 Transfer Prices

The price of each certificate and the total quantity purchased under the transferability clause of the TCP (Florida Statute 370.142(2)a.1) is reported on the notarized Spiny Lobster Trap Certificate Transfer Form.

During the 1994 season, almost half of all transactions for A-1 certificates and one-third of transactions involving Type B certificates were reportedly exchanged at the base price (i.e., the annual certificate fee). By 1998, the proportion of reported base prices fell to 17% and 7%, respectively, for Type A-1 and B certificates. The transactions that involved base prices were likely not reliable reflections of the actual price used in exchange. This is because it was unlikely that a seller would knowingly sell a trap certificate for $0.75 when the current annual harvest per trap was approximately 12 pounds, the ex-vessel price per pound was approximately $3.80, and the certificate could be used as long as the TCP is in effect. The reporting of minimum prices is presumed, therefore, to result from the 25% surcharge since a lower reported price translates into a lower total payment to the State. Since it is possible that minimum reported prices may not reflect the true exchange price, the average prices are calculated using only non-base prices. These "trimmed" average transfer prices are shown in Figure 3.

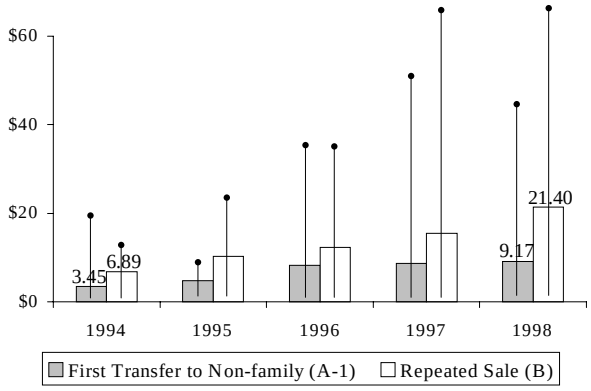

Figure 3. Average and Extreme Certificate Transfer Prices by Certificate Type

The average prices for A-1 and B certificates rose approximately 168% and 211%, respectively, from 1994 to 1998. The average B prices were higher than the average A-1 prices in each year. Consequently, the reported A-1 certificate prices were likely under-reported. For example, in 1998, the average price for a B certificate was more than 130% above than the reported average price of an A-1 certificate.

The standard deviations associated with the trimmed average prices increased over time reflecting the increase in the highest reported transfer prices from less than $20 to nearly $70 per certificate. In Figure 3 the range of reported prices are identified with vertical lines. Note that increases in the reported highs are substantially above the averages and may reflect an increase in the perceived value and/or confidence in the program.

In summary, factors that have influenced the reported transfer prices include: (a) the novelty of transferable ownership rights under the TCP; (b) uncertainty about the duration of the program; (c) uncertainty about future certificate reductions including the specification of the total number to be reduced and effects on yield per trap; (d) market imperfections such as difficulty in finding a willing buyer or seller with the desired number of certificates; (e) the surcharge applicable on the transfer of A-1 certificates to non-family members; (f) leasing activity that reduces the market for sales; and (g) potential underreporting of actual sale price. The combination of these factors has contributed to reported average prices that are lower than reasonable estimates of their expected market value, which are based on annual yields and current market price. These average reported prices are also lower than those specified in local newspaper advertisements (Milon et al. 1998).

3.5 Administrative Revenues and Costs

The last piece of information relating to the performance of the TCP is whether the revenues derived from the program have covered the implementation costs and annual expenses. In each year, the certificate fee has accounted for the majority of TCP revenues. The relative importance of this revenue source has varied, however, with the annual fee and the volume and value of transfers. Revenues from the annual certificate fee have increased by more than 46%, from $326,909 in 1993 to $477,988 in 1997. In addition, total revenue from the fee is expected to generate nearly $525,000 in the 1998-99 season. Revenues from certificate transfers have remained relatively stable over the past three years despite a decrease in the total number of certificates, a decline in the total number of certificates traded, and an increase in the average sales price. These figures do not include revenues from permits required to participate in the fishery since they are not a part of the TCP.[3]

[3] Of these permits, only the crawfish trap license is unique to the spiny lobster fishery. Since the fee is $100 per license, revenues have been significantly affected by the reduction in the number of fishers described earlier.

Revenues projected prior to program implementation overestimated actual revenues by 65% in the first season. The initial projections estimated revenue at $684,375, but only $412,989 was reported for 1993. Approximately 5% of the initial overestimate is due to the difference between the number of certificates allotted (724,232) and the assumed number (750,000). The projected revenues also assumed that the annual fee would be collected on all available certificates; however, approximately 5% of the certificates were inactive in 1993. This discrepancy accounts for an additional 13% of uncollected revenue. The total transfer revenue (fees plus surcharges) in the first year was estimated at $309,375, but only $86,080 was collected. Specifically, 82% of the overestimate was due to incorrect assumptions regarding transfers. The majority of the overestimate resulted from an incorrect assumption regarding the transfer price, the assumed $25 per certificate sales price was approximately $20 higher than the reported average price (Figure 3). Given that reported transfer prices averaged less than $5 per certificate, the projected surcharge revenue overestimated the actual revenue by $217,187.

The State of Florida initially projected the annual recurring cost of the TCP to be approximately $270,000. This estimate excluded miscellaneous expenses and costs associated with data processing, research, and the appeals board. Collectively, these excluded costs averaged approximately $200,000 in fiscal years 1995 through 1997. Consequently, excluding these expenses significantly underestimated total costs. In 1995, the projected cost of the TCP was 26% less than actual expenses. The majority of the discrepancy involved costs associated with the tags. The original budget underestimated the costs of producing and distributing the tags by 42% and salary expenses by 10%. In addition, miscellaneous expenses totaling over $33,000 (for supplies, notices of impending regulatory changes, room rental for public meetings, and legal advice) were not considered in the original budget.

Annual costs incurred from 1995 through 1997, the only period for which detailed costs data was available, ranged from approximately $467,000 to over $518,000. Costs were incurred for research, office operations, data processing, meetings of the appeals board, salaries associated with the program, production and distribution of the trap tags, and miscellaneous (unspecified) division expenses. Overall, the most expensive component of the program (accounting for, on average, 55% of total costs) is the cost to produce and distribute the tags.

Using the official certificate numbers and reported transfer activity, revenues can also be approximated for the 1997-98 season. Assuming a 95% payment rate, the $0.75 per certificate annual fee would generate $431,005.50. The transfer of 35,042 certificates would generate $70,084, given the $2 per certificate transfer fee, and surcharge revenues for first-time out-of-family sales were reportedly equal to $20,144.82. Consequently, total revenues for the 1997-98 should be approximately $521,234, resulting in a net profit of $24,812 assuming costs remain unchanged.

Future costs are assumed to remain at the 1996-97 level since reductions in the number of trap tags are assumed to offset increases in production and distribution costs. Revenues from the annual certificate fee are determined by the number of available certificates in the 1998-99 season, the mandated reduction in 2000 (assuming an exact 10% reduction), and a 95% payment rate. Although the annual fee accounts for the majority of revenues, revenues are also collected on transfers. There are two sources of transfer revenue, the $2 per certificate fee and a recently authorized minimum $5 per certificate surcharge on the value of transfers to non-family members. To estimate transfer revenues, assumptions must be made regarding the transfer rate (i.e., number or percentage of total certificates expected to be transferred), the average price, and the percentage of transfers subject to the surcharge. Given the importance of each assumption to the resulting net revenue figure – and assessment of the self-sufficiency of the program – three transfer assumptions are compared in Table 1. The first transfer assumption represents a minimum estimate of total revenues by assuming no transfers occur. The second assumes the lowest reported transfer rate (5.8%) and out-of-family sales rate (41.2%) – both of which were observed in the 1997-98 season. Under the third scenario, the surcharge is assumed to equal 25% of the "fair market value" of a certificate (i.e., 25% of $66.67, which assumes a 5-year horizon and 10% discount rate).

Table 1. Projected TCP Net Revenues Excluding Law Enforcement and Expenses Incurred by the Commission

Projections	FY98-99	FY99-00	FY00-01
No Transfers			
Revenue	$ 516,859	$ 516,859	$ 465,173
Cost	496,422	496,422	496,422
Net Revenue	20,437	20,437	-31,249
Transfers @ $5			
Revenue	644,974	644,974	580,477
Cost	496,422	496,422	496,422
Net Revenue	148,552	148,552	84,055
Transfers @ $16.67			
Revenue	796,695	796,695	717,052
Cost	496,422	496,422	496,422
Net Revenue	$ 300,273	$ 300,273	$ 220,603

The first scenario approximates the minimum expected revenue situation. This scenario would represent fishermen choosing to lease certificates, rather than buy, in order to avoid the newly-instituted $5 minimum transfer surcharge. Under this scenario, net revenues would decrease from approximately $20,000 to a net loss of more than $31,000 following the next reduction. Although this scenario assumed costs were equal despite the reduction, the costs of tag production and distribution will most likely increase. In addition, recall that these costs excluded law enforcement and expenses incurred by the Commission. The revenues, however, also excluded potential transfer revenues. Although these revenues are only collected if transfers are reported (i.e., the revenue is not guaranteed) and will decrease as the total number of certificates subject to a surcharge falls, it is likely that some revenues will be collected.

Under the second assumption, net revenue would equal approximately $148,500 during the 1999 and 2000 seasons then fall to $84,000 with the reduction in 2000. The increased annual revenue over the first scenario is divided roughly equally between the $2 transfer fee and $5 surcharge on out-of-family transfers. Under these transfer assumptions, total transfer revenues account for 80% of total revenues. When the assumed surcharge is increased to the expected value of the certificate, the transfer revenue increases significantly and net revenues in the first two years increase to more than $300,000 (i.e., 102%). In addition, transfer revenues would account for 35% of total revenues instead of 20%. This scenario would represent the optimistic case where all respondents reported the true value of the transfers.

4. BIOECONOMIC ANALYSIS

Bioeconomic theory for a commercial fishery posits that the socially optimal level of catch and effort is determined by the biological dynamics of the stock, harvesting costs, and the market price of the product. This is because society is interested in stock conservation and the profitability of the industry. From society's point of view, the maximum economic yield (MEY) is the optimal solution since industry effort is increased only to the point where additional revenues are offset by harvesting costs. This solution is identified by equating the slopes of the total revenue and total cost curves (i.e., where marginal revenue equals marginal cost).

To estimate an MEY solution for the Florida commercial spiny lobster fishery, we must first estimate a sustainable yield curve. The sustainable yield curve, also known as the surplus production function, describes the aggregate effects of natural mortality, growth, and recruitment in a single compensatory function. According to Menzies and Kerrigan (1980), surplus production models can be used when the relationship between the local stock size and future recruitment is weak or unknown. In addition, these models have relatively modest data requirements and are particularly useful as first approximations (Clarke et al. 1992). The shape of this curve depends on assumptions regarding the growth rate of the stock. For example, the traditional logistic (Schaefer) model assumes a density-dependent growth pattern whereby the sustainable annual harvest is dependent on the size of the local population in previous years. This specification is characterized by the potential for complete depletion of the stock since catch can be driven to zero at excessive levels of effort.

Recent studies have concluded that spiny lobster recruitment in Florida is dependent, at least in part, on the size of the spawning stock in waters adjacent to Florida (Ehrhardt 1994). In addition, the Florida fishery prohibits harvest (1) during spawning season, (2) of egg-bearing females, and (3) of juvenile (undersize) individuals. According to Clarke et al. (1992), if recruitment into a fishery is exogenous or local regulations are sufficient to maintain recruitment, a logarithmic production function is most appropriate. A logarithmic production function assumes the sustainable yield is not entirely dependent on stock size so increasing effort eventually has no effect on total catch; the sustainable yield curve has a "flat-top." With this model specification, there is potential for a wide range of effort to generate the optimal harvest level. Thus, even if the biological relationship indicates that additional effort will not threaten sustainability of the stock, the bioeconomic framework shows that it is necessary for management to restrict effort in the fishery to achieve an economically efficient allocation of resources.

4.1 Biological Production Models

With a logarithmic specification, the catch (C) function is given by:

$$C = C_{\max}(1 - \exp^{-qE}) \qquad (1)$$

where the catchability coefficient (q) is a shape parameter that describes the rate at which the yield curve approaches the asymptotic catch level ($C_{\max}$) as fishing effort (E) increases. The catchability coefficient reflects the dynamics of trap density on yield. Catch is estimated as the difference between the asymptotic catch minus the potential catch that survives fishing effort. Consequently, this model is distinct from the logarithmic models estimated for the Hawaiian Islands fishery (Clarke et al. 1992; Coppola and Pascoe 1998). This model is unique

in that it explicitly incorporates trap density into the estimation of the surplus production function.

Equation (1) was estimated using a non-linear least squares procedure with seasonal data from 1960-61 to 1997-98. The production model fit the data well as the F-value was significant ($F_{2,34}$ = 661.2). C_{max} was estimated at 6,180,829.52 pounds and q at 1.2976E-05 with asymptotic standard errors of 202,454.89 and 0.019E-05, respectively. This model predicts modest increases in catch up to approximately 400,000 traps, at which point additional traps do not increase catch. This trend in decreasing marginal productivity corresponds with the observed characteristics of the fishery.

Since Florida accounts for less than 10% of total U.S. disappearance, it was assumed that the real price was constant at the average 1996 of $3.79 per pound (National Marine Fisheries Service 1998). Using these production model results and product price, the total revenue function was given by:

$$TR = \$3.79[6{,}180{,}829.52(1-\exp^{-0.000012976E})] \qquad (2)$$

The marginal revenue curve was obtained by taking the derivative of *TR* with respect to effort.

4.2 Cost of Production Models

The cost equation specified the total annual cost of participating in the lobster industry for firm i (TC_i) as a linear function of the number of traps the firm operated (E_i):

$$TC_i = \$14{,}901 + 29.73E_i \qquad (3)$$
$$(6{,}602) \quad (7.01) \qquad R^2=0.50$$

Equation (3) provides an estimate of the annual fixed cost for lobster fishing ($14,901) for each vessel and the corresponding marginal cost per trap ($29.73). Both parameters were significant at the 5% level as indicated by the standard errors in parentheses. By providing an estimate of fixed costs, equation (3) is most representative of short-run costs. Alternatively, by assuming all costs depend on the variable input (i.e., effort), a long-run specification for marginal cost per trap was estimated:

$$TC_i = \$38.81E_i \qquad (4)$$
$$(18.83) \qquad R^2=0.87$$

Equation (4) is appropriate for a long-run analysis because it yields the minimum point on the long-run average cost curve if all markets are competitive (Clarke et al. 1992). The long-run specification estimated marginal costs per trap at $38.81, nearly 31% above the short-run cost estimate, and was a better fit.

Linear cost curves, such as in equations (3) and (4), assume the cost for the fishery increases in direct proportion to effort. That is, each additional trap, when operated in the most efficient manner, can be added to the fishery at the same cost as the previous one (Anderson 1986). A linear cost curve also implies that units of effort are homogeneous, which is valid due to the long-standing regulations on trap size and construction.[4]

4.3 Integrated Bioeconomic Analysis

Two MEY solutions were found by equating the two marginal revenue curves (*MR*) with the two marginal cost estimates (*MC*). The economically optimal solutions and range of corresponding effort levels (E^*) are shown in Figure 4. For comparison, the current effort level ($E_{2000\text{-}01}$) is also indicated.

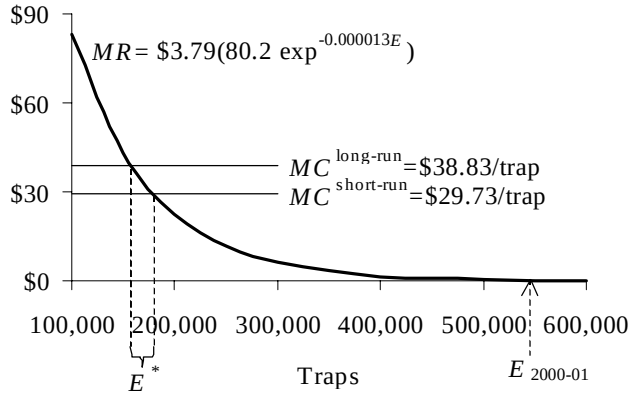

Figure 4. Bioeconomic MEY Solutions

The short-run marginal cost estimate resulted in a higher optimal effort level of 179,159 traps. At this effort level each trap would yield approximately 31 pounds each year and generate $76.58 in profits. The long-run cost function predicted an optimal effort level of 158,619 traps. Each trap would yield 34 pounds annually and

[4] The appropriateness of the cost specification was examined by including a nonlinear effort term and dummy variables for vessel length and number of traps (as shifters and to change slope). A multiproduct function was also estimated to test for jointness. None of the alternative specifications had sufficient explanatory power to reject the linear specification (Milon et al. 1999).

generate a profit of $90.02. Industry profits ranged from $13.7 million to $14.8 million.

Using the long-run cost curve resulted in fewer traps and lower landings but higher landings per trap. It is notable that the range of MEY solutions encompasses early estimates by Prochaska and Cato (1980) who found 169,335 traps landing 31 pounds per trap annually would maximize net revenues. Also, our estimates are consistent with survey data from the early 1970s that showed average trap yields of 35 pounds per trap when approximately 147,000 traps were in the fishery (Williams and Prochaska 1976).

From the bioeconomic analysis, we know the value of each certificate (trap) if the total number of traps were optimal (i.e., from approximately 160,000 to 180,000). If the transfer market for trap certificates was working properly (e.g., buyers and sellers can exchange easily and at a reasonable cost), the observed certificate transfer price should closely match the estimated optimal certificate value. The difference between the average reported price of a certificate and the estimated optimal certificate value could be used as a rough approximation of the gains from certificate reductions, that is, the gains to moving toward the MEY solution. Such a comparison could also reveal the potential "equitable rent per trap" that the State is allowed to collect.

5. CONCLUSIONS

Market-based systems have been advocated by economists for fisheries management as an alternative to command and control approaches that discourage efficiency and innovation. In the context of fisheries management in the United States, the potential for individual harvesters to continually re-allocate shares of restricted inputs or outputs through an unregulated market has been advanced by many (e.g., Squires et al. 1995), most recently by the National Research Council (1999). Yet uncertainty about the effects of market-based quasi-rights programs has led to a Congressional moratorium on new programs in federal fisheries management until at least October 2000 and more is known about the performance of existing programs.

The Florida spiny lobster TCP is an example of a fishery that is managed with a transferable input share program. Under the TCP, the total effort (input) level is restricted but individuals can trade units of effort between seasons through a market-like process administered by the state. Through periodic reductions in the total effort level, the TCP has succeeded in reducing effort from open-access levels but efficiency gains have been ambiguous. The lack of significant gains has fueled dissention among a core group of participants, especially small firms that are loosing market share. This vocal minority, coupled with declining revenues to the state from continued reductions and a thin transfer market, is likely to preclude further movement toward the economically efficient effort level. In addition, the structure of the TCP makes it unlikely that the move towards optimal levels of effort will occur without major revisions in the program or other aspects of the management of this resource. For example, recent reductions (although specified at the 10% maximum) were implemented only every other year. Under this schedule the reductions needed to reach MEY would take nearly to two decades. This prolonged schedule delays potential benefits, requires fishers to continually purchase certificates to return to efficient production levels, and undermines the support for the program. In addition, thus far the program has neglected the option tax rents generated by this fishery, an option that is legislated. Given that the procedure to tax rents has not been identified, it would probably be contentious if established at this point.

In conclusion, the elusive appeal of a social surplus from restricting entry in the Florida spiny lobster fishery may not be sufficient to overcome both industry and regulatory incentives for the status quo. This is evidenced in part by the fact that no further reductions are scheduled. The Florida TCP has suffered due to a lack of a clear definition of program objectives, specification of a terminal effort level, and the structure of administrative costs to fund the program. The most significant of these oversights, the failure to identify the extent of the certificate reductions, is particularly troublesome given that prior to implementation of the TCP the National Marine Fisheries Service, the State of Florida, and industry members agreed that optimal yield would occur with 195,000 to 375,000 traps (Florida Fish and Wildlife Commission 1999). A liberal goal, with the option of further reductions following evaluation of the fishery, would have been better than no goal. Other market-based quasi-right input share systems for other fisheries have little chance of succeeding and virtually ensure that the transition will not be smooth if such details of the program are neglected.

6. REFERENCES

Anderson, L. *The Economics of Fisheries Management*. Baltimore: Johns Hopkins University Press, 1986.

Clarke, R.P., S.S. Yashimoto, and S.G. Pooley, A bioeconomic analysis of the Northwestern Hawaiian

Islands lobster fishery, *Marine Resource Economics 7*, 115-140, 1992.

Coppola, G. and S. Pascoe, A surplus production model with a nonlinear catch-effort relationship, *Marine Resource Economics, 13*, 37-50, 1998.

Ehrhardt, N.M., The lobster fisheries off the Caribbean coast of Central America, in *Spiny Lobster Management*, B.F Phillips, J.S Cobb, and J. Kittaka, eds. Cambridge: Blackwell Science Publishers, 133-143, 1994.

Florida Fish and Wildlife Commission, Spiny lobster, Tallahassee: Florida Department of Environmental Protection, December 1999.

Hunt, J.H., W.C. Sharp, T.R. Matthews, R.G. Muller, R.D. Bertelsen, and C. Cox, *Status of the Spiny Lobster Fishery in Florida in 1998*. Marathon: Florida Department of Environmental Protection, 1998.

Labisky, R.F., D.R. Gregory, Jr., and J.A. Conti, Florida's spiny lobster fishery: An historical perspective, *Fisheries, 5(4)*, 28-37, 1980.

Menzies, R.A. and J.M. Kerrigan, The larval recruitment problem of the spiny lobster, *Fisheries, 5(4)*, 42-46, 1980.

Milon, J.W., S.L. Larkin, and N. Ehrhardt, *A Bioeconomic Analysis of the Florida Spiny Lobster Fishery*. Gainesville: Florida Sea Grant, Report Number 117, 99 pp., 1999.

Milon, J.W., S.L. Larkin, D.J. Lee, K.J. Quigley, and C.M. Adams, *The Performance of Florida's Spiny Lobster Trap Certificate Program*, Gainesville: Florida Sea Grant, Report 116, 71 pp., 1998.

National Marine Fisheries Service, *Fisheries of the United States, 1996*, Current Fishery Statistics No. 9700, Silver Spring, 168 pp., 1998.

National Research Council, *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*, Commission on Geosciences, Environment, and Resources. Washington: National Academy Press, 1999.

Prochaska, F.J. and J.C. Cato, Economic considerations in the management of the Florida spiny lobster fishery, *Fisheries, 5(4)*, 53-56, 1980.

Squires, D., J. Kirkley, and C.A. Tisdell, Individual transferable quotas as a fisheries management tool, *Review of Fisheries Science, 3*, 141-169, 1995.

Williams, J.S. and F.J. Prochaska, *The Florida Spiny Lobster Fishery: Landings, Prices, and Resource Productivity*, Gainesville: Florida Sea Grant, Report Number 12, 24 pp., 1976.