Implications of Optimal Effort Reductions in the Florida Commercial Spiny Lobster Fishery

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ABSTRACT

An integrated bioeconomic analysis – using alternative surplus production and harvesting cost functions – provided a range of effort that would maximize economic yield in the Florida commercial spiny lobster fishery. Despite a 35% trap reduction since 1992, when a transferable harvest rights program was implemented, effort remains too high and trap certificates appear undervalued. It is unlikely that the optimal effort level will be achieved under the existing program given the lack of a reduction goal, prolonged reduction approach, and waning support for the program from delayed benefits. A comprehensive long-range management plan is needed to reap the benefits – economic and environmental – that were predicted and desired from the trap certificate program.

KEY WORDS: Bioeconomic model, fisheries management, surplus production model

INTRODUCTION

Florida's spiny lobster (*Panulirus argus*) fishery is one of the state's most important fisheries, ex-vessel landings were valued at nearly $30 million in 1996 (NMFS 1997). From 1960 to the early 1990s, commercial fishing effort expanded from less than 100,000 traps (the dominant gear type) to more than 900,000 (Hunt 1994). Despite the significant increase in effort, total commercial landings varied little, fluctuating between 2,400 and 3,580 metric tons (mt) per year since 1969. Even though the significant increase in effort did not have an effect on landings that would cause concern for the health of the stock, it did raise several other concerns. In 1991, 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)).

The number of traps was eventually regulated in 1992 when the Florida

Legislature implemented the Trap Certificate Program (TCP). The mandated goal of the TCP is "to stabilize the fishery by reducing the total number of traps, which should increase the yield per trap an d therefore maintain or increase overall catch levels" (Florida Statute 370.142(1)). The TCP ended an era of open-access management of the spiny lobster fishery in Florida by establishing a cap on total effort. The program is one of the first individual transferable effort programs in the United States. Under the TCP, qualified commercial fishers own "certificates" that entitle the owner to fish a specified number of traps (each certificate allows the use of one trap). All traps are identical, since trap size and design are regulated. Each year, fishers pay an annual certificate fee ($1.00 in 1998 - 1999) 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.

The total number of certificates, which is considered a proxy for the total level of effort allowed in the fishery, has been periodically reduced in accordance with the stated goal of the program (Florida Statute 370.142(1)). The Statue that established the program did not, however, specify the total number of traps to eliminate from the fishery. Since 1992, periodic reductions in the total number of certificates have eliminated approximately 35 percent of the commercial traps (Milon et al. 1998). It is not clear, however, whether these reductions have been too much or too little relative to an "optimal" (e.g., profit maximizing) number of traps in the fishery.

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 regulatory actions have achieved an economically optimal and sustainable number of traps in the fishery. This was accomplished by estimating biological production and harvesting cost models for use in an integrated bioeconomic analysis. The second goal was to assess the effects of moving the fishery toward the optimal solution. The evaluation of these effects will focus on the number of participants, the market for trap certificates (including observed prices and transfers), and the implications for future management of the fishery.

MODELING APPROACH

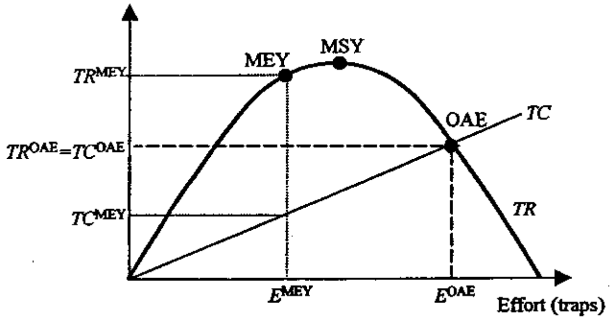
Bioeconomic theory for a commercial fishery posits that the socially optimal level of catch and effort is determined by the biological dynamics of the stock, harvesting costs, and the products' market price (Hartwick and Olewiler 1998). This is because society is interested in stock conservation and the profitability of the industry. Without entry or effort restrictions, harvest continues to the breakeven point -- an effort level where total revenues just cover total costs (*TR* = *TC*) – which is known as the open-access equilibrium (OAE). Using the well-known Schaefer (logistic) yield-effort curve, and assuming constant costs and prices, the OAE solution is shown in Figure 1(a) (Gordon 1954). The OAE (unregulated) equilibrium is socially inefficient (suboptimal) because the same total revenue can be achieved at a lower cost. At the OAE solution the additional effort incurs additional costs, which completely offset the total revenues (profits are zero). In addition, the level of catch at OAE is less than at the maximum sustainable yield (MSY), which occurs at the height of the total revenue (*TR*) curve. The relative catch levels can be identified using the *TR* curve since the *TR* curve retains the same shape as the underlying sustainable yield (catch-effort) curve when price is constant. The MSY catch level represents the largest quantity that can be harvested on a sustainable basis (i.e., without compromising the stock); it is the harvestable surplus. Throughout the remainder of the analysis the terms catch, yield, harvest, and landings (variable *C*) will be used interchangeably.

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 (Gordon 1954). This solution is identified by equating the slopes of the total revenue and total cost curves (i.e., where marginal revenue equals marginal cost). TR^{MEY} minus TC^{MEY} represents the maximum profit per unit effort in the fishery. In the traditional example shown in Figure 1(a), the MEY effort is less than needed to take the MSY. This solution would also provide the maximum rents to the fishery if costs included the opportunity cost of capital and labor (i.e., the market value of alternative uses for the resources). Since opportunity costs are often difficult to measure in fisheries, most empirical studies attempt to measure only profit changes (Hartwick and Olewiler 1998).

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, Yoshimoto, and Pooley 1992). The shape of this curve depends on assumptions regarding the growth rate of the stock. For example, the traditional logistic model in Figure 1(a) 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, Yoshimoto, and Pooley (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, such as shown in Figure 1(b), assumes the sustainable yield is not entirely dependent on stock size so increasing effort eventually has no effect on total catch.

1(a) Logisitic (Schaefer) Production Function



1(b) Logarithmic Production Function

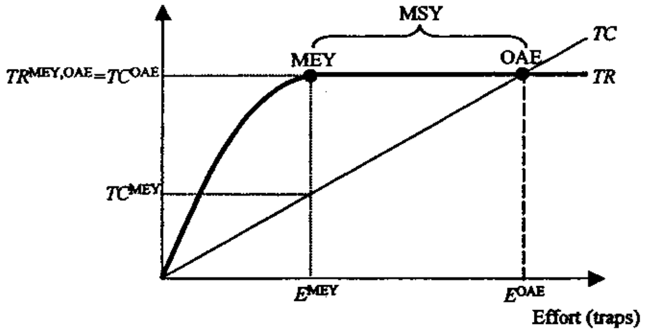


Figure 1. Equilibrium solutions with alternative production functions

As illustrated in Figure 1(b), a logarithmic or "flat-top" sustainable yield curve has a wide range of effort levels that produce the MSY solution. Effort at the open-access equilibrium (E^{OAE}) is greater than effort that maximizes economic yield (E^{MEY}). Since total revenues are the same at either E^{MEY} or E^{OAE}, society is not making the best use of its resources by increasing effort from E^{MEY} to E^{OAE}. The additional effort at the OAE solution dissipates profits that would be earned at E^{MEY} since costs are higher. 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.

DATA

Catch and effort data, as well as records of certificate transactions 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 for the 1960 - 1961 through 1997 - 1998 seasons. Data reported on the East Coast from 1964 to 1975 were adjusted to remove landings and traps associated with fishing in the Bahamas (data and correction details are available in Milon, Larkin, and Ehrhardt 1999). Landings are the quantity purchased (whole weight) by licensed wholesale dealers and are assumed to equal total catch (C). Fishing effort (E) is the total number of traps operated by commercial fishermen. It is implicitly assumed that fishing practices have not changed over time and do not differ among fishers. These are valid assumptions given that trap size and construction have been regulated since the 1960s (Milon et al. 1998). Also, fishing technology changes may have increased the rate of harvest – which is accounted for in the cost information and biological coefficients – but would not have affected resource availability and, therefore, estimation of the surplus production function. These data exclude the recreational sector since statistics are not available for the entire period and effort is measured differently. Omitting the recreational data will not, however, affect the shape of the production function since recreational landings have remained a relatively constant share of total landings since recreational data collection began in 1991 (Hunt et al. 1998).

Annual landings in Florida averaged approximately 1,500 mt during the 1960s, but have averaged 2,850 mt since and fluctuated without an 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 average trap yields to fall approximately 75 percent from 1970 to 1990. Since the TCP was implemented in 1992 the number of traps has been reduced to approximately 544,000 (Milon et al. 1998).

Cost data needed to estimate the marginal cost per trap were obtained during interviews conducted with a stratified sample of lobster fishers (*n* = 53) in the Florida Keys (Milon, Larkin, and Ehrhardt 1999). Variable costs included trip costs (fuel, bait, groceries, ice, supplies, and labor payments), equipment leasing and repair, and maintenance expenses incurred during the 1996-97 season. These costs averaged $16,366 per vessel exclusive of labor. Labor payments equaled $12,950 assuming the captain and crew were paid 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 labor costs on the minimum wage provides an estimate of the minimum opportunity cost associated with work hours expended in this fishery. Fixed costs averaged $21,238 per vessel annually and included interest payments, docking fees, depreciation (vessels and gear), and licensing.

RESULTS

Biological Production Models

Two flat-top production models were estimated for this fishery. The empirical models and corresponding catch-effort curves are shown in Figure 2. The first, dubbed the "Effort-Corrected Schaefer" model, incorporated the effects of trap density into a traditional Schaefer production model by specifying the catch rate as an inverse function of total effort. In addition, a relative trap efficiency parameter was estimated and used to standardize effort over time. Both parameters in the Effort-Corrected (E-C) Schaefer model were statistically significant at the one percent level and the estimated model was highly significant overall ($F_{1,34} = 69.9$). The second flat-top production model, referred to as the "Biomass Utilization" model, assumed that catch was a function of the catch rate and the maximum catch possible. As with the E-C Schaefer model, the catch rate in the Biomass Utilization (BU) model incorporated the effect of trap density on yield. Catch was estimated as the difference between the asymptotic (maximum) catch minus the catch that survived fishing effort. This model is unique in that catch is a function of the available "catchable" biomass without taking population regeneration into consideration. Using the nominal data, the estimated BU model was statistically significant at the one percent level ($F_{1,34} = 71.1$). See Milon, Larkin, and Ehrhardt (1999) for further detail.

Figure 2 shows the relationship between the total number of traps and sustainable landings predicted by each model. Both models predict landings would increase at a decreasing rate until approximately 400,000 traps. Landings would then remain constant at approximately 2,800 mt as effort increased.

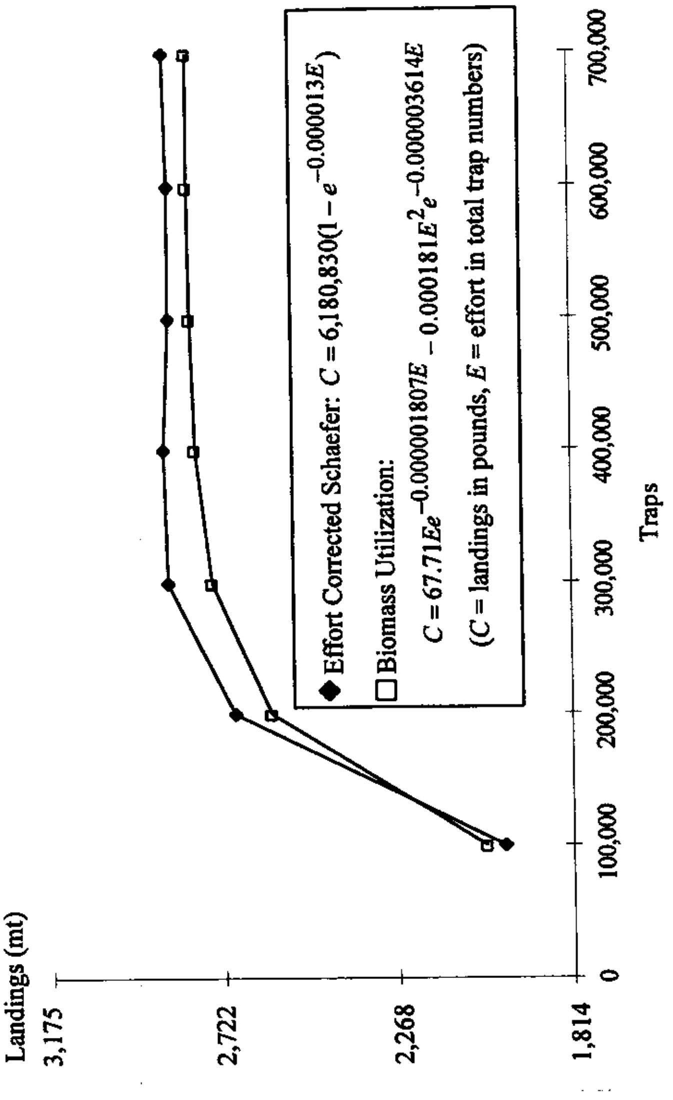


Figure 2. Estimated biological production functions: C - f(E)

Cost of Production Models

Two cost models were estimated for this study. The first followed Prochaska and Cato (1980) in which the total annual cost of lobster fishing for each vessel (TC_i) was regressed against the number of traps operated by the firm (E_i): $TC_i = \alpha + \beta E_i$. This equation provided an estimate of the annual fixed cost for each vessel (α) and the corresponding marginal cost per trap (β). The costs estimated from this specification represent the short-run costs of fishing. The second model assumed all costs are variable and, in particular, depend on the level of effort (i.e., number of traps fished): $TC_i = \beta E_i$. T his is the appropriate specification for a long-run analysis.

The two cost models were estimated using a least squares estimator with the 1996 - 1997 survey data. Both marginal cost estimates were statistically significant at the one-percent level. The short-run cost curve estimated annual fixed costs at $14,901 and marginal cost at nearly $29.73 per trap ($R^2 = 0.50$). The long-run cost curve estimated marginal cost at $38.81 per trap ($R^2 = 0.87$), approximately 30 percent above the short-run cost.

Integrated Bioeconomic Analysis

Four OAE solutions were found by equating the two total revenue curves (*TR*) – for the E-C Schaefer and BU models – with the short- and long-run total cost curves (*TC*). These solutions, where profits are driven to zero, occur at effort levels between 565,729 and 614,269 traps. For comparison, the fishery was operating at approximately 605,000 during the 1996 - 1998 seasons (Milon et al. 1998). Average yields under the OAE solutions ranged from 4.6 to 5.0 kg per trap, closely matching observed yields. Table 1 summarizes the OAE solutions.

Table 1 also includes a description of the four MEY solutions, which were found by equating the two marginal revenue curves (*MR*) with the two marginal cost estimates (*MC*). The marginal revenue curves were derived by multiplying the estimated marginal productivity curves (i.e., the slope of the biological production functions in Figure 2) by the average unit price in 1996 ($8.36 per kg, NMFS 1997). The profit-maximizing number of traps in the fishery ranged from 158,619 to 198,523, each yielding from 13.5 to 15.4 kg for total landings of 2,446 mt to 2,681 mt. Industry profits ranged from $13.7 million to $14.8 million, or $71 to $90 per trap. 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 15.5 kg annually would maximize net revenues. Also, these estimates are consistent with survey data from the early 1970s that showed average trap yields of 14.5 kg per trap when approximately 147,000 traps were in the fishery (Williams and Prochaska 1976).

Table 1. Range of Equilibrium Solutions

	Total Revenue Specification			
	OAE Solutions		MEY Solutions	
Cost Specification	Biomass Utilization	E-C Schaefer[a]	Biomass Utilization	E-C Schaefer[a]
Short-run Cost:[b]				
Effort (E^*)	565,729 traps	575,592 traps	179,159 traps	198,523 traps
Catch (C^*)	2,802 mt (5.0 kg per trap)	2,851 mt (5.0 kg per trap)	2,529 mt (14.1 kg per trap)	2,681 mt (13.5 kg per trap)
Total Profits	$0	$0	$13,720,529 ($77 per trap)	$14,182,009 ($71 per trap)
Long-run Cost:				
Effort (E^*)	603,350traps	614,269 traps	158,619 traps	178,655 traps
Catch (C^*)	2,803 mt (4.6 kg per trap)	2,853 mt (4.6 kg per trap)	2,446 mt (15.4 kg per trap)	2,599 mt (14.5 kg per trap)
Total Profits	$0	$0	$14,278,428 ($90 per trap)	$14,785,497 ($83 per trap)

[a] Where $q = 0.000001807$.

[b] Assuming each vessel fished 1,279 traps (the sample average) in order to calculate total fixed costs.

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 200,000). If the transfer market for trap certificates is 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.

IMPLICATIONS

The bioeconomic analysis revealed that if reductions were to continue until the economically efficient number of traps is reached, economic efficiency in the fishery would reach a maximum. Certificate values would range from $70 to $90 per certificate, which translates to earnings of 77 to 128 percent above average annual costs reported during the 1996 - 1997 season (assuming 1,279 traps per vessel). However, the MEY solutions occur at effort levels that are approximately 35 percent of current trap numbers. The need for significant effort reductions should be expected to affect fishery participants, the market for certificates, and the future management of the fishery. The implications of such reductions for each sector are considered below.

Industry Participants

The bioeconomic analysis indicates that future effort reductions in the commercial spiny lobster fishery could significantly increase the profit per trap and the value of certificates. The estimated optimal number of traps, however, could imply a significant reduction in the total number of vessels in the fishery. For example, using the average number of traps per vessel (1,279) reported in the recent cost study by Milon, Larkin, and Ehrhardt (1999) and the optimal MEY effort levels from this study (158,619 to 198,523; Table 1), optimal fleet size would range from 124 to 155 vessels. Each vessel would earn profits of from $91,497 to $115,149 annually assuming 1996 costs and $8.36 per kg price. A fleet of 124 vessels represents a 75 percent reduction in the number of full-time operators. Although the TCP contains restrictions that ensure at least 76 certificate owners, greater concentration of certificate ownership can have effects on other segments of the industry. For example, fewer harvesters could cause consolidation in the processing sector and further reduce employment. Previous reductions have not, however, significantly increased concentration in the Florida spiny lobster fishery (Milon et al. 1998).

Certificate Market

During the 1996 - 1997 season, 604,920 certificates were available – approximately three times the optimal number of traps – and reported certificates prices averaged from $4.47 to $15.52 depending on the certificate type and calculation method (Milon et al. 1998). Although lower than the price that would be expected if the number of traps were near optimal (i.e., $70 - $90, table 1), these prices are near the value expected with the current number of traps (544,000 in 1998 - 1999). For example, given an average annual yield of 5.8 kg per trap and average price of $8.36 per kg, gross returns are approximately $48.50 per trap. Net returns would range from $9.69 to $18.77 using the estimated long- and short-run marginal costs, respectively. For comparison, the annual profit per trap from the BU model would equal $13.30 at the 1998-99 certificate level. Consequently, the trap values from the estimated bioeconomic models are similar to the average transfer prices reported to date.

The total number of certificates, volume of certificate transfers, and certificate composition (by type) is important since each affects the revenue collected by the State of Florida. The total number of certificates determines the maximum annual revenue from certificate fees, which were $1 for the 1998 - 1999 season. If reductions were to continue toward the MEY solution, certificate fee revenue would decrease proportionately. The volume of certificate transfers is important since each certificate transferred is subject to a $2 fee. The number of certificates transferred annually fell from approximately 91,000 in 1994 to just over 35,000 in 1998 (Milon et al. 1998). If the total number of transfers continues to decline, so will the revenue collected by the State of Florida. A decline in the number of certificates and transfers can further reduce revenues by reducing surcharges, which depend on the type of certificate transferred. There are three types of certificates. Certificates originally issued are Type A-1. Certificates sold to an immediate family member are Type A-2 and are exempt from a transfer surcharge. Certificates sold to non-family members are Type B and are subject to a one-time transfer surcharge equal to 25 percent of the value of the transaction. From 1993 to 1999, the composition of certificates changed as the number of Type B certificates increased to 31 percent of the total (Milon et al. 1998). The percentage of Type B certificates is important since the State of Florida will not collect a surcharge from the subsequent transfer of these certificates. Revenue reductions to the State of Florida could compromise the fiscal self-sufficiency of the TCP.

Future Management

The bioeconomic optimal solutions (MEY), which maximize rents to the industry, offer several advantages over the open-access alternative. First, there would be a reduction in the amount of labor needed in the fishery, which could increase returns to certificate owners. Second, it would eliminate excess gear. Fewer traps would reduce the negative environmental consequences (e.g., debris and "ghost" fishing) from lost and abandoned traps. The relatively low cost of a trap is a disincentive to retrieve traps at the conclusion of the season. Lastly, the MEY solution allows for the possibility of residual rents. Resource managers could redistribute, if desired, a portion of the increased returns to the citizens of Florida in the form of an "equitable rent per trap" as stipulated in the original legislation (Florida Statute 370.142(2)).

Moving the industry toward the MEY solution could also create additional management issues that need to be addressed. For example, there would likely be impacts on local communities and other fisheries as participants are initially displaced. On the other hand, increased rents could attract effort from other fisheries and cause poaching and illegal trap use, requiring the need for increased enforcement of regulations. Of course the status quo situation, which is near the open-access (OAE) solution, will need to contend with many of these issues regardless of the course of action pursued.

DISCUSSION

The Florida spiny lobster TCP was implemented to alleviate several problems faced by rapid growth in the industry including: declining trap yields, increased congestion and conflict on the water, and environmental concerns from trap debris (Florida Statute 370.142(1)). The program allocated trap certificates, defined a mechanism to periodically reduce certificates, and allowed transfer of ownership. However, the TCP failed to state an overall effort reduction goal even though estimates were available (e.g., Prochaska and Cato 1980, Waters 1996). Consequently, six years after implementation, there has been little effect on trap yields, which is not surprising given that effort reductions fall far short of the estimated reductions needed to reach MEY in the fishery. The relatively slow adjustment to lower effort levels is due, in part, to the 10% cap on annual reductions. This approach lowers subsequent reductions, which slows the movement toward the optimal solution. Since the beneficial effects of trap reductions are not expected until total trap numbers fall below 300,000, at least six future reductions are required to see results. Ten reductions in total would be required to achieve the MEY range of optimal effort estimates. In addition, with the alternate year reduction schedule (which began with the 1998 - 1999 reduction), the MEY level would not be reached until 2019. It is unlikely that support for the program could be maintained over the 20 years needed to show these results. As Johnson and Libecap (1982) suggest "fishermen are more likely to support arrangements that do not affect status quo rankings and that increase their total catch – such as season closures, hatcheries, gear restrictions to protect juvenile fish, and controls on fishing by members of other groups."

This is because "those programs raise rents for existing fishermen above open access conditions, even though dissipation continues along other margins. In the absence of political support from fishermen, politicians, and bureaucrats facing periodic reelection and budget review will not pursue efficiency goals in regulation if the programs are controversial, as is likely" (Johnson and Libecap 1982, p. 1019).

The bioeconomic analysis and the evaluation of the TCP provide valuable insights into the strengths and weakness of one of the nations first transferable rights programs. It provides an example of how economic analysis can be used to evaluate the effects of one approach to correcting problems in fisheries management. The lack of a measurable goal (i.e., number of certificates to be eliminated) has already led to dissention between resource managers and fishers that has undermined the effectiveness of the program (by delaying effort reductions) and compromised future reductions. Consequently, there is an immediate need for a more comprehensive approach to deal with program goals and the mechanisms to achieve those goals (Milon et al. 1998)

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