Shrimp - Finfish Interaction

JOHN M. WARD
National Marine Fisheries Service
Southeast Regional Office
9450 Koger Blvd.
St. Petersburg, FL

ABSTRACT

Economic and technical efficiency are terms often confused by the managers of marine resources. Technical efficiency is an engineering concept that deals with the ability of a piece of capital to produce a good, such as the efficiency of gear in the harvesting of a fish stock. Managers often assume that technically inefficient gear is the best approach to prevent overfishing of a resource stock. Economic efficiency deals with determining the best use of the resources employed in the production of a set of goods, such as in the harvesting of a stock of fish. In the shrimp fishery, over-investment in capital and labor have resulted in both an economically inefficient allocation of resources to harvest shrimp and a high finfish discard rate. Using a quasi-dynamic graphical analysis, three alternative shrimp management approached (finfish separators, taxes, and individual transferable quotas) are analyzed in terms of their impacts on economic efficiency and equity in the harvest of shrimp and finfish stocks. The management policy that corrects the common property problem in the shrimp fishery results in:

- a reduced finfish discard rate,
- lower shrimp fishing costs in conjunction with the use of the most efficient fishing gear, and
- an equitable reallocation of resources (capital, labor, and fishery stocks) to their best use by society.

INTRODUCTION

Changing consumer preferences for seafood and the resultant increasing unit prices in conjunction with the lack of property rights have resulted in the over-investment of capital and labor in the harvesting of shrimp. One byproduct of increased shrimp harvesting effort is the taking of a significant level of finfish bycatch. [Blomo and Nichols (1974) found that four pounds of finfish were landed for every pound of shrimp. A study conducted by Chittenden and McEachran (1976) found a ten to one ratio. Bryan (1980) found a three to one ratio. In 1985, Pellegrin *et al.* found a range of finfish to shrimp ratios from 2 : 1 to 21.1 : 1. The results vary by the area surveyed and the time of year the studies were conducted.] In the case of the Gulf of Mexico shrimp fishery, Nichols *et al.* (1987) found that the estimated bycatch of red snapper, king mackerel, and Spanish mackerel are comparable to or exceed the average recreational catch. In some cases, this bycatch is marketed and contributes to the income of the shrimp fishermen or to the profits of the shrimp fishing firm. In most cases, however, the bycatch is not in a form that has market value to the fishermen. This portion of the bycatch is discarded dead by the shrimp fishermen and is not recruited into the commercial or recreational finfish fishery (Pellegrin *et al.*, 1985).

Given the magnitude of the finfish bycatch, the shrimp fishing gear interdependencies that cause the finfish bycatch, and the lack of property rights for the shrimp and finfish resources, the economic impacts of alternative management scenarios need to be considered before bycatch regulations are placed into effect. The reduction or elimination of finfish bycatch in shrimp fishing operations would require the adoption of regulations affecting the efficiency of the gear (finfish separators) or the revenue generated by fishing (landings tax or individual transferable quotas). As with the presently existing area closure off Texas and TED regulations, alternative proposed bycatch regulations will have significant economic impacts on the shrimp fishery in the Gulf of Mexico in addition to the economic impacts in the finfish fisheries. For example, Powers *et al.* (1987) found that the elimination of red snapper shrimp bycatch would result in a ninety percent increase in the stock of fish available to recreational and commercial finfish fishermen.

To accurately reflect the effects of these bycatch regulations, the cost benefit calculations must include the direct and indirect effects on the shrimp and related finfish fisheries. Comparisons of cost benefit ratios for various management regulations such as finfish separators, taxes on landings, or individual transferable quotas (ITQ) determines the management policy that comes closest to correcting the property rights problem in the shrimp fishery, reduces the finfish bycatch and discard rate, allows for the lowest shrimp fishing costs in conjunction with the use of the most efficient fishing gear, and reallocates capital and labor resources to their best use by society.

SHRIMP FISHERY MANAGEMENT SCENARIOS

Three management measures that could reduce or eliminate the finfish bycatch in the shrimp fishery are discussed. A finfish separator installed in the shrimp otter trawl would eliminate bycatch by allowing the finfish to escape from the fishing gear unharmed. A tax on shrimp landings or individual transferable quotas (ITQ) would reduce the effective price received by shrimp fishermen, reduce fishing effort, and reduce but not eliminate the total level of bycatch. Although each of these management measures reduces fishing effort and the corresponding overcapitalization and excessive use of labor in the shrimp and finfish fisheries, they have different equity effects for the fishermen involved in harvesting the resource.

Finfish Separators

A finfish separator is a technological device that changes the technical efficiency of the shrimp fishing gear by allowing finfish to escape capture without reducing shrimp landings. [Technical efficiency is an engineering

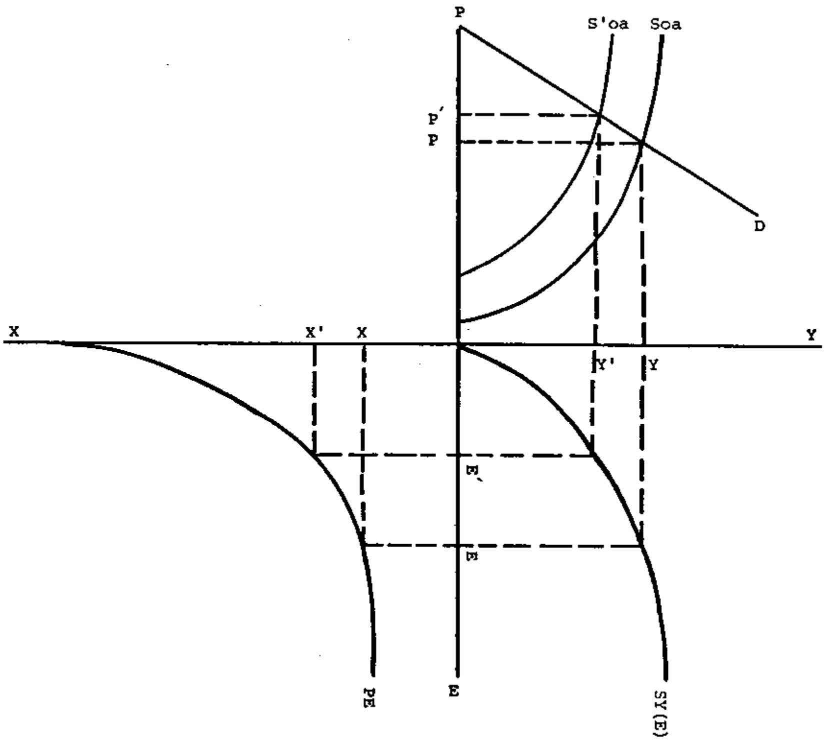

Figure 1. Shrimp fishery.

concept that deals with the ability of a piece of capital to produce a good, such as the efficiency of gear in the harvesting of a fish stock.] Regulations requiring shrimp vessels to employ such a device would force some shrimp fishermen from the industry because of the loss of revenue from finfish landings and increased costs of harvesting shrimp. The resulting decline in shrimp supply should increase the price final consumers would have to pay. These costs to society would be at least partially offset by the benefits that accrue to the harvesters and consumers of finfish.

The Gulf of Mexico shrimp fishery can be represented by the graph in Figure 1. The first quadrant represents the open access supply (S_{oa}) of shrimp and the market demand for shrimp (D). The fourth quadrant is the sustainable yield effort curve (SY(E)) for shrimp. Quadrant three is the population equilibrium curve (PE) (Anderson, 1977). Since the shrimp otter trawl is best suited to harvest shrimp on flat muddy bottoms, shrimp are distributed over the entire Gulf of Mexico, and no yield-per-recruit relationship is reported to exist (Rothschild and Brunenmeister, 1984), yield (Y) and biomass (X) size are assumed to approach an asymptote as effort (E) is increased. As a result, the open access supply curve approaches a vertical asymptote rather than being characterized by the traditional backward bending supply curve of fishery economics theory. The intersection of market demand (D) and open access supply (S_{oa}) result in a market price (P) and landings or yield (Y) for the shrimp fishery. The sustained yield effort curve (SY(E)) in quadrant four indicates that this level of landings (Y) can be maintained with (E) units of fishing effort. This level of fishing effort (E) supports a shrimp biomass of size (X) according to the population equilibrium curve (PE) in quadrant three.

The requirement that shrimp vessels employ finfish separators causes the total cost of vessel operations to increase. Gear purchase and maintenance and repair are generally attributed to variable costs of fishing effort in the literature since they occur only if the vessel or firm plans to operate in the associated fishery (Blomo *et al.*, 1978). Variable costs increase because the purchase price of the fishing gear has risen to reflect the cost of the finfish separator and its associated maintenance and repair costs. Vessels operating at the margin in the shrimp fishery exit the fishery, and the existing vessels that remain in the fishery reduce their individual levels of fishing effort. [The margin is defined as the point where average cost equals marginal cost equal marginal revenue and no economic profits exist. That is, the fisherman is operating where his profits are just equal to the opportunity cost of his labor, *i.e.* he can receive no higher return for his labor, in some other employment.] The open access supply curve declines from (S_{oa}) to (S_{oa}') in the graph in Figure 1. This decline in supply reflecting the higher costs of the shrimp fishing gear results in a decline in landings (Y′) and an increase in the exvessel price (P′) of shrimp. Shrimp fishing effort declines to E′ and shrimp biomass increases to X′. Even though the technical efficiency of shrimp fishing gear in the harvest of shrimp is assumed to be unaffected by the finfish separator [No change has occurred in the sustained yield effort curve (SY(E)) in quadrant four of the graph in Figure 1.], and the lost value of any marketed portion of the bycatch is ignored, the increased costs of fishing have resulted in a decline in net revenue for producers and higher prices for consumers [The magnitude of this decline in social welfare will depend on the elasticity of demand for and supply of shrimp.].

The elimination of finfish bycatch in the shrimp fishery has a positive impact on the finfish stocks as represented by Figure 2. The initial equilibrium of market demand (D) and open access supply (S_{oa}) results in a price (P) and landings level (Y) that is maintained by effort level (E) with a finfish biomass of (X). The finfish bycatch that was discarded by the shrimp fishery before the adoption of the finfish separator can now be recruited into the commercial and

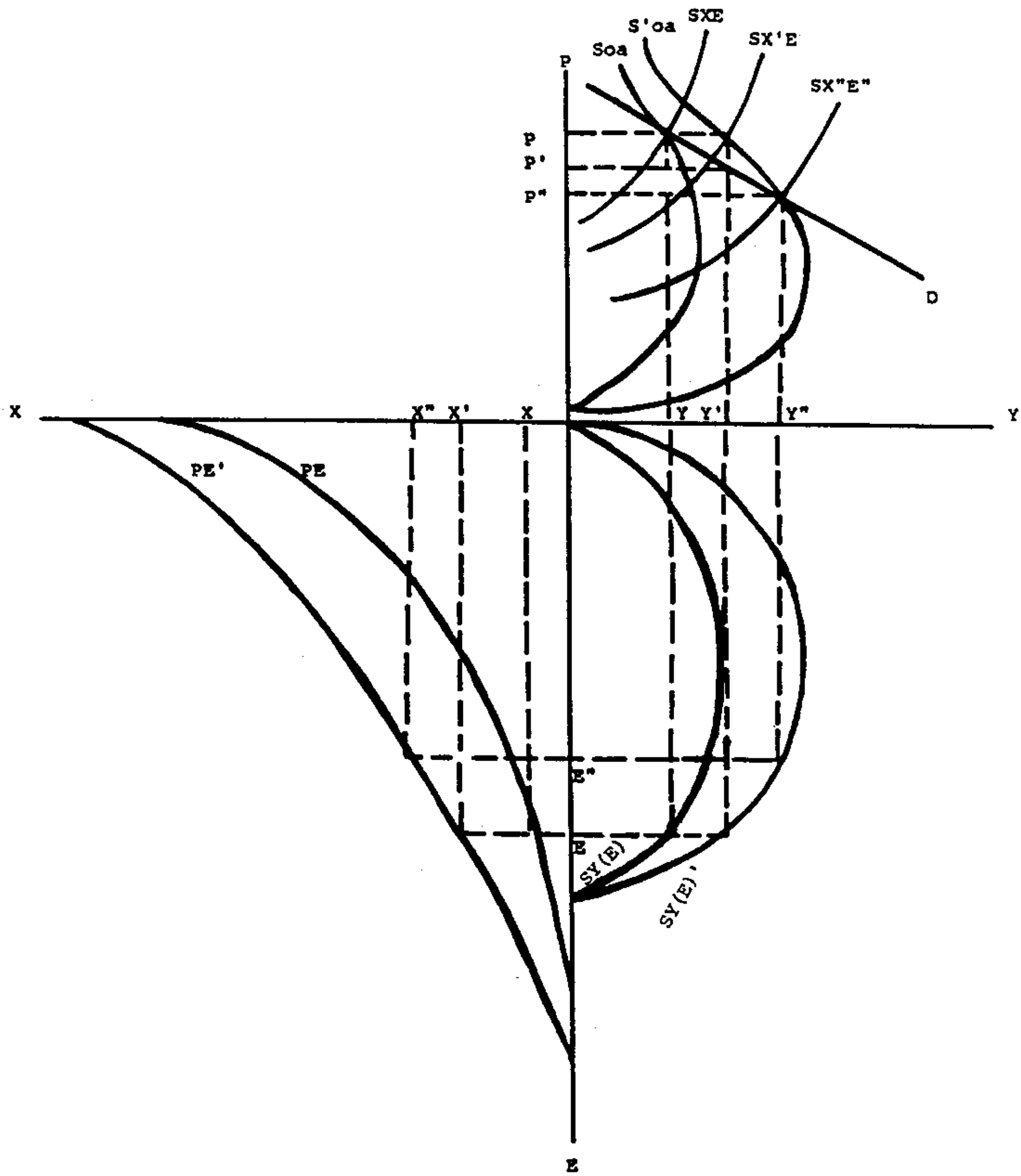

Figure 2. Finfish fishery.

recreational finfish fishery. The sustained yield effort curve (SY(E)) in quadrant four and the population equilibrium curve (PE) in quadrant three of Figure 2 shift outward (SY(E)´ and PE´) reflecting the reduced bycatch of finfish by the shrimp fishery. If price remained constant at (P), the same fishing effort level (E) by the finfish fishermen could result in a higher level of landings (Y´) and an increased biomass (X´). Because the biomass has increased (X´ > X), the stock constant supply curve (S_{XE}) shifts outward to ($S_{X'E}$). [Sutinen, J. personal communication. While the open access supply function reflects equilibrium levels of biomass (X), the stock constant supply function holds biomass levels constant. Since it is assumed that the costs of fishing decline with increased stocks of fish, the stock constant supply curve increases with increases in biomass (X).] At this level of landings (Y´) and effort (E), the costs of fishing represented by (P * Y´) are greater than the revenue from fishing represented by (P´ * Y´). These negative profits cause fishermen to exit the finfish fishery causing effort to decline from (E) to (E´´). Fishing effort (E´´) is below the sustained yield effort curve in quadrant three which allows the biomass to grow from (X´) to (X´´) and causes the stock constant supply curve to increase from ($S_{X'E}$) to ($S_{X''E''}$). [Total costs are assumed to increase with increases in fishing effort (E). Declines in fishing effort as a result cause the stock constant supply function to increase (shift outward) reflecting these lower costs of vessel firm operation.] The new equilibrium price (P´´) is less than the initial price (P) and landings have increased (Y´´ > Y´). Net revenue has increased for producers and prices for consumers have declined resulting in increased social welfare; however, fishing effort levels have declined. The decline in fishing effort could be represented by a reduced effort level by individual fishermen and by the exit of some marginal finfish fishermen.

The lack of property rights in the finfish and shrimp fisheries leads to a decline in fishing effort when finfish separators are required to eliminate finfish bycatch by shrimp fishing vessels. Society is better off since the increased costs represented by a higher shrimp price to consumers and lower net revenues to the shrimp fishermen are offset by the increased benefits represented by the lower finfish price paid by consumers and increased net revenues of finfish fishermen. However, the potential exists for the displacement of both shrimp and finfish fishermen who are operating at the margin in these over-capitalized fisheries characterized by excessive use of labor. These fishermen who are forced to exit the fisheries may move into other fishing operations (nonbycatch fisheries) or they may lose their capital investment and take jobs in shore based industries or become unemployed.

Taxes

A tax on the level of landings can be applied to either the shrimp catch or to the bycatch of finfish. [Although not allowed under the Magneson Fishery

Conservation and Management Act, a landings tax's effect on the fishing industry and individual fishermen is interesting from an equity perspective.] A tax on the bycatch of finfish would create an economic incentive for shrimp fishermen to avoid areas of known high bycatch rates and to adopt gear that reduces bycatch. Besides the obvious enforcement problem (bycatch is discarded at sea), the appropriate tax rate would require knowledge of the discounted value of the bycatch when it is recruited into the commercial and recreational finfish fishery. The appropriate tax on shrimp landings would be easier to estimate since the shrimp landings are known, and the shrimp have already been recruited into the fishery. However, the shrimp landings tax would reflect the social value of the shrimp resource not the finfish resource. Although the bycatch and the discard rates of individual shrimp vessels would remain unchanged, the total level of bycatch would be reduced because shrimp fishing effort would decline to a level considered more appropriate by society.

By imposing the appropriate tax on shrimp landings, the management authority acting as the sole owner of the shrimp resources appropriates that portion of total revenue that represents the lease fee the fishermen would have to pay to the owner of the shrimp resource if property rights existed in the shrimp fishery. This can be represented as a reduction in the price the shrimp fishermen receives for each unit of shrimp landed (Clark, 1985). The decline in unit shrimp price causes the supply curve (S_{oa}) in Figure 3 to shift upward to (S_{oa}'). If stock size (X) and fishing effort (E) are assumed fixed initially, the stock constant supply curve declines from S_{XE} to S_{XE}' reflecting the decline in revenue caused by the tax. Since the costs of producing the fixed landings of (Y) are greater than the revenue generated by the landings ($P''*Y > P*Y$), fishing effort (E) declines to (E′) where the stock constant supply curve (S_{XE}') intersects demand (D) at price (P′) and landings (Y′). Fishing effort (E′) and landings (Y′) represent a point below the sustained yield curve (SY(E)) which allows the stock size to increase to X′. This increase in stock size causes the stock constant supply curve (S_{XE}') to increase back to (S_{XE}) with landings level (Y); the original equilibrium position with a lower level of fishing effort.

Although the individual vessel bycatch has not changed, the decline in fishing effort represented by the exit of the marginal shrimp fishing vessel results in a reduction in total bycatch by the shrimp fleet. [It could be argued that the bycatch rate of the more skilled captains who operate the more efficient shrimp vessels is lower than that of the marginal vessel that is forced to exit the fishery.] This reduction in bycatch in the shrimp fishery results in an increase in recruitment for the finfish fishery. Although the population equilibrium (PE), sustained yield effort (SY(E)), and open access supply (S_{oa}) curves for the finfish fisheries shift out less because some bycatch still occurs, the same general results hold for the landings tax scenario as were presented in Figure 2 for the finfish separator case.

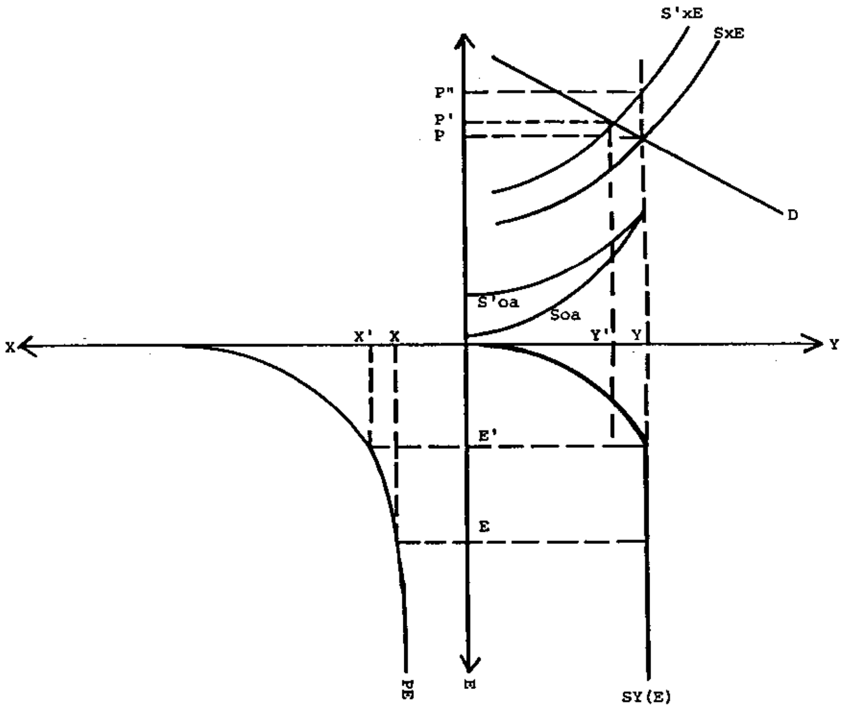

Figure 3. Shrimp fishery, landings tax, individual transferable quota.

Since the incidence of the shrimp landings tax is on the revenue received by the shrimp fishermen, losses to consumers in the form of higher prices is a short term effect of this management measure. However, producer's net revenue declines as a result of the tax on shrimp landings. This decline in social welfare in the shrimp fishery is offset by the increase in net benefits to consumers and producers in the finfish fishery. Whether the net benefits to society are larger under the tax or finfish separator management scenarios cannot be determined without information on the magnitude of the shifts in supply and demand, knowledge of the changes in the level of bycatch, and information on the elasticity of supply and demand in the finfish and shrimp fisheries. The potential does exist for the displacement of both shrimp and finfish fishermen from the harvesting industry, but funds are generated in the case of the landings tax that could be used by society to relocate and retrain the displaced fishermen.

Individual Transferable Quotas

Individual transferable quotas (ITQ) have the same effect on the shrimp and finfish fisheries as a landings tax if a competitive quota market exists. Fishing effort in the shrimp and finfish fisheries will decline as fishermen exit the industry. The long run decline in shrimp fishermen net revenue will be offset by the increased net benefits generated in the finfish fishery. However, the competitive market will determine the appropriate ITQ price (m) based on the exvessel shrimp price, the costs of harvesting shrimp, the size of the stock, etc., and the total quota level. The management authority no longer needs to estimate the appropriate fee to charge fishermen for the right to harvest shrimp as in the tax case.

The management authority chooses a total quota (Q) that can be harvested each year by the shrimp fishing industry that corresponds to the landings level (Y) in Figure 3. This total quota is divided up among the individual shrimp fishermen who have the option for purchasing, selling, or holding the individual transferable quota. This ability to buy, sell, or hold quota results in the establishment of a quota market (Figure 4) where the price (m) for ITQ is a function of the total quota (Q) available, cost of fishing, shrimp price, and the stock of shrimp (X). As the stock of shrimp increases, for example, the costs of fishing decline by assumption and net revenue generated by the shrimp harvesting operation increases. The increase in net revenue would give shrimp fishermen an incentive to purchase more ITQ which would cause the demand curve (D) to increase (shift to the right) and given the fixed total quota (Q) cause ITQ price (m) to increase. The ITQ price (m) should represent the discounted net revenue generated by the harvest of the shrimp resource.

Since each unit of shrimp landed by the shrimp fisherman must be accompanied by a corresponding ITQ, the fisherman's net revenue declines by the purchase price (m) of the ITQ. As in the case of a landings tax, the decline in revenue causes the open access and stock constant supply curves in Figure 3 to decline, fishermen exit the fishery causing a decline in fishing effort although individual vessel costs are not affected by the ITQ price (m), and landings decline in the short term to (Y') but in the long run increase to (Y) with the growth of the resource stock to (X'). Although individual vessel bycatch is unchanged, total bycatch declines reflecting the exit of fishermen from the shrimp fishery. This allows additional finfish to be recruited into the finfish fishery and as in the case of the tax a decline in fishing effort and an increase in net benefits for society from increased landings and reduced prices.

If the management authority can determine the appropriate tax that corresponds to the annual stock size and desired landings level, then the impact of the tax and the ITQ on the shrimp and finfish fisheries will be identical. The incidence of the landings tax and unit price of the ITQ on revenue is the same for shrimp fishermen, but the equity effects could be different. The ITQ could be

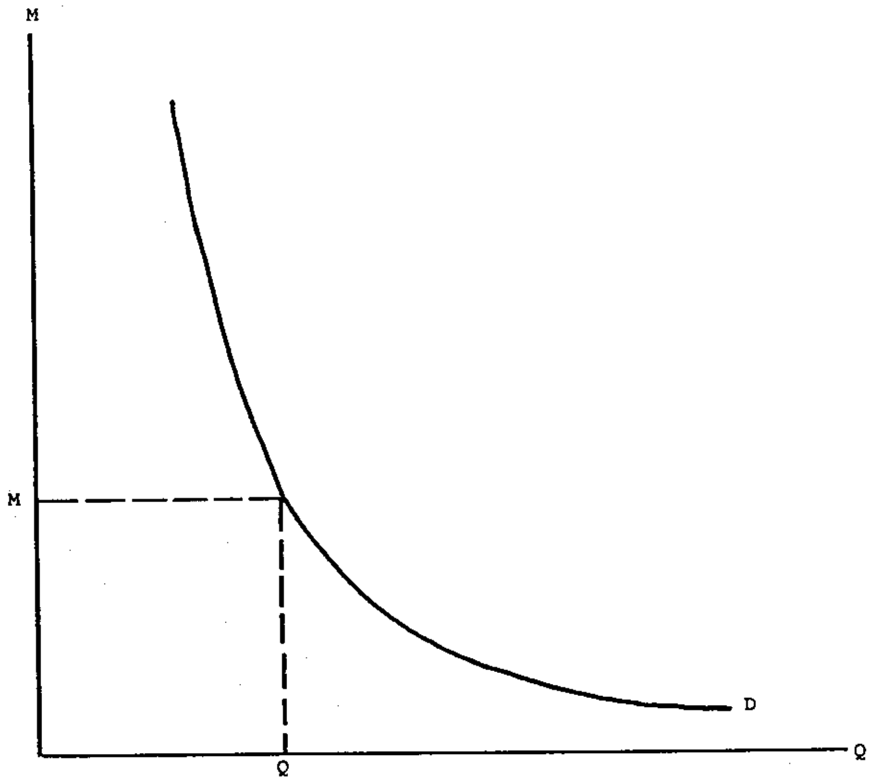

Figure 4. Demand for individual transferable quotas.

allocated to the shrimp fishermen based on a historical landings scheme. If the ITQ price which reflects the discounted net revenue from harvesting shrimp is greater than the discounted net revenue a shrimp fisherman could generate from fishing, he would be better off selling his ITQ and leaving the shrimp fishery. The shrimp fishermen receive a windfall when they exit the fishery since they did not have to pay for their initial allocation. Alternatively, the management authority could allocate the quota through an auction. The auction would result in revenues equivalent to the discounted revenue raised by the landings tax regulation and could be used by the management authority as it saw fit. The plan used to effect the initial ITQ allocation would affect the length of time before benefits began to appear in the finfish fisheries and would have to be determined in an empirical analysis.

CONCLUSIONS

The use of finfish separators in the shrimp fishery reduces the technical efficiency of shrimp fishing gear, increases the costs of fishing, and results in a long run decline in consumer and producer net benefits and a deadweight loss of benefits to society. The offsetting increase in net benefits in the finfish fisheries from the elimination of bycatch can also be achieved by the use of landings taxes or the adoption of individual transferable quotas without the consumer benefit loss from higher shrimp prices. The tax measure generates funds that the management authority could use to fund any social program, such as training and relocating fishermen forced out of the fishery. Revenues generated from an initial ITQ auction could be used similarly or if allocated based on historical landings, fishermen could sell out and use the funds generated to train themselves or retire.

Each of these management measures that reduce the finfish bycatch in the shrimp fishery reduce the level of labor and capital invested in the shrimp and finfish harvesting sectors. Which approach generates the highest net benefits can be determined by a joint biological and economic analysis that considers the direct and indirect effects of the different bycatch reduction measures on the finfish fisheries. However, without some form of limited entry in both fisheries, increases in consumer demand for seafood will eventually eliminate these benefits as overcapitalization and excessive use of labor in the finfish fisheries reappear in response to increasing prices. In Figure 2, this could be represented by a shift to the right in the demand curve (D) causing price to increase and landings to decline when equilibrium was restored to the system. The increase in net benefits from the adoption of bycatch regulations in the shrimp fishery would disappear as fishing effort increased in the finfish fishery. Consumer price increases and the decline in producer net revenues would leave society worse off.

LITERATURE CITED

Anderson, L.G. 1977. *The economics of fisheries management.* Johns Hopkins University Press, Baltimore.

Blomo, V.J. and J.P. Nichols. 1974. Utilization of finfishes caught incidental to shrimp trawling in the western Gulf of Mexico, part 1: Evaluation of markets. Sea Grant Publication No. TAMU-SG-74-212, Tex. A&M University, 85 pp.

Blomo, V.J., W.L. Griffin, and J.P. Nichols. 1978. Catch-effort and price-cost trends in the Gulf of Mexico shrimp fishery: Implications on Mexico's extended jurisdiction. *Marine Fisheries Review*, August, pp. 24-28.

Bryan, C.E. 1980. Organisms captured by the commercial shrimp fleet on the Texas brown shrimp (*Penaeus Aztecus* Ives) grounds. Masters Thesis, Corpus Christi, Tex., 44 pp.

Chittenden, M.E., Jr. and J.D. McEachran. 1976. Composition ecology and dynamics of demersal fish communities on the northeastern Gulf of Mexico continental shelf with a similar synopsis for the entire Gulf. Sea Grant, Publication No. TAMU-SG-76-208, Tex. A&M University, 104 pp.

Clark, C.W. 1985. *Bioeconomic Modelling and Fisheries Management*. John Wiley and Sons, New York. 159 pp.

Nichols, S., A. Shah, G. Pellegrin Jr., and K. Mullin. 1987. Estimates of annual shrimp fleet bycatch for thirteen finfish species in the offshore waters of the Gulf of Mexico. NMFS, SEFC, Miss Lab., Pascagoula Facility, Pascagoula, MS., Oct.

Pellegrin, G. Jr., S. Drummond, and R. Ford Jr. 1985. The incidental catch of fish by the northern Gulf of Mexico shrimp fleet. NMFS, SEFC, Miss Lab., Pascagoula, MS., July.

Powers, J., C. Phillip Goodyear, and G.P. Scott. 1987. The potential effect of shrimp fleet bycatch on fisheries production of selected fish stocks in the Gulf of Mexico. NMFS, SEFC. Miami Lab., Coastal Resource Division CRD-87/88-06, Nov.

Rothschild, B.J. and S.L. Brunenmeister. 1984. The dynamics and management of shrimp in the northern Gulf of Mexico. *In* J.A. Gulland and B.J. Rothschild, eds. *Penaeid shrimps-their biology and management*. Fishing News books Limited, England.