AN ECONOMIC ANALYSIS OF SPINY LOBSTER PRODUCTION BY INDIVIDUAL FIRMS AT OPTIMUM STOCK LEVELS

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Spiny lobster *(Panulirus argus)* landings in Florida increased from 1.9 million pounds in 1954 to 6.6 million pounds in 1974 [1], a gain of 239 percent. Florida landings currently account for 94 percent of U.S. spiny lobster landings. Total Florida spiny lobster landings have declined since 1974 for two reasons. First, prohibition of Florida fishermen from lobster fishing on the Bahamian continental shelf reduced landings considerably. Florida landings declined approximately 3.5 million pounds between 1974 and 1975, mainly because of the loss of the domestic landings which were caught in Bahamian waters. Second, domestic landings from Florida waters appear to have reached a maximum in 1974 and have since remained relatively stable or declined slightly.

U. S. demand for spiny lobster increased considerably more than domestic production in the past two decades. The resultant higher prices have caused considerable expansion of effort in the fishery. The rapid increase in inputs has caused declining catch rates, overinvestment, and a potential for overexploitation of the spiny lobster stock. The need for an effective management program is recognized by the industry, management personnel, and researchers.

Management of the fishery is appropriately considered at two levels. One is the aggregate industry level where total fishing effort is considered over time and where the long-term effect of fishing on the stock is of prime importance.[1] The other management level is that of the individual fishermen who must determine the economically efficient level of effort to devote to a given stock level. Also appropriate in context of the second management level is analysis by management personnel of expected effects of fishery regulations at given stock levels. That is, if fishing effort is to be regulated, what effect will alternative plans have on economic efficiency and what alternatives are available for management?

In 1976, an economic analysis was completed for alternative management strategies in the Florida spiny lobster industry. Two models were estimated. First, a bioeconomic model relating yield to fishing effort over time where the biological stock was allowed to vary was estimated to provide data for evaluating and designing aggregate industry level management strategies [3, 4]. A second model was estimated to represent an individual firm's harvest function for 1974 stock levels.

The authors' study, relating to the second management level, is an analysis of the firm's harvest function. The model was estimated to determine production relationships for the 1973-1974 stock level which is particularly significant because subsequent time series research [3, 4] and recorded landings [1] have suggested that the 1973-1974 season was near the optimum level in terms of sustainable catch in Florida waters.

The purpose of the analysis was to provide information for decision making for individual lobster firms and to provide estimates of production relationships for use in the analysis of aggregate industry level management programs which might be imposed at current or optimum stock levels. Spiny lobsters have been designated as a management unit by the Fishery Management Councils authorized by the Fishery Conservation and Management Act of 1976 [2].

The Florida Keys region, the study area, provides more than 80 percent of Florida domestic landings of spiny lobsters. A random stratified sample was taken, which consisted of 25 interviews of lobster fishermen (firms), to obtain information on production inputs, costs, landings, prices, fishing techniques, and area fished.

THEORETICAL MODEL

Spiny lobster production is carried out by individual private firms. Each firm consists of one boat and one captain. Often no crewmen are involved other than the captain. Because of the relatively shallow inshore water, fishing

[1] "Effort" as used throughout this article refers to any or all of the input variables—traps (x_1), rounds per week fished (x_2), weeks fished (x_3), and craft size (x_4). Also, "stock" is defined as the total biomass of spiny lobsters that may be landed.

trips are of one day or shorter duration. Approximately 95 percent of the commercial harvest is done with spiny lobster traps [1].

In this analysis the trap represents the principal unit of effort through which the traditional factors of production (labor, capital, and management) are employed. The intensity with which traps are fished was included in the analysis through variables measuring the frequency with which traps were pulled each week and the number of weeks fished. These intensity variables adjust trap use among firms in the cross-sectional survey and also represent additional use of traditional production variables such as labor and capital. Variation in firm size and capital investment was included by a proxy variable defined to be the square footage of the boat or vessel.

A Cobb-Douglas type of mathematical functional form was selected for the production function because it allows for either increasing, constant, or decreasing returns in response to changes in level of fishing effort. In addition, this model requires fewer degrees of freedom to derive the interactive effect among the independent variables measuring fishing effort. The model is summarized in equation 1.

$$q = \alpha x_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} x_4^{\beta_4} e^{\beta_5 x_5} e^{\beta_6 x_6} \qquad (1)$$

where

- q = landings per firm
- x_1 = traps fished per firm
- x_2 = proportion of total number of traps pulled each week
- x_3 = number of weeks fished
- x_4 = craft size
- x_5 = zero-one variable representing upper Keys region
- x_6 = zero-one variable representing lower Keys region
- $\alpha, \beta_1, \ldots \beta_6$ = parameters to be estimated.

Landings per firm (q) were measured in pounds landed per boat during the 1973-1974 season. Average traps fished per firm (x_1) represents the average number of traps fished during the season. Estimates of x_1 were based on the number of traps fished at the beginning of the season, number of traps lost during each month of the season, and the number of times a trap was fished before lost. Rounds per week (x_2) was defined as the average proportion of traps pulled per week by each firm for the season. One round represents the pulling of all traps once a week. Total number of weeks fished (x_3) in Florida is limited to a maximum of 36 weeks by law, which defines the fishing season. Not all fishermen choose to fish the total 36 weeks because mackerel fishing and stone crabbing are more profitable during the latter stages of spiny lobster season. Firm size and/or capital investment (x_4) was measured with a proxy variable defined as the square footage of the hull.

Variations in harvest levels due to quality differences in fishing grounds caused by biological or physical factors were accounted for by including a qualitative variable having three categories. The upper and lower Keys are represented by x_5 and x_6, which are zero-one variables, and the middle Keys region is the omitted category.

The upper Keys region (x_5) was defined as the 44 miles from Key Largo to lower Matecumbe Key, Florida. The lower Keys region (x_6) was defined as the 31 miles from Big Pine Key to Key West. The middle Keys region, the base region, was defined as the 37 mile stretch between the other two areas. The zero-one variables allow the intercept or position of the harvest function to vary for different fishing areas.[2]

The estimated parameters β_1, β_2, β_3, and β_4 represent the percentage change in landings due to a 1 percent change in variables x_1, x_2, x_3, and x_4, respectively. These parameters are defined as partial output elasticities.

Estimated effects on landings per firm of an additional unit of effort, other effort variables held constant, are referred to as marginal products and are determined by partial differentiation of equation 1. Marginal products for the respective effort variables are represented by equations 2 through 5.

$$MP_{x_1} = \frac{\partial q}{\partial x_1} = \alpha \beta_1 x_1^{\beta_1 - 1} x_2^{\beta_2} x_3^{\beta_3} x_4^{\beta_4} e^{\beta_5 x_5} e^{\beta_6 x_6} \qquad (2)$$

$$MP_{x_2} = \frac{\partial q}{\partial x_2} = \alpha \beta_2 x_2^{\beta_2 - 1} x_1^{\beta_1} x_3^{\beta_3} x_4^{\beta_4} e^{\beta_5 x_5} e^{\beta_6 x_6} \qquad (3)$$

$$MP_{x_3} = \frac{\partial q}{\partial x_3} = \alpha \beta_3 x_3^{\beta_3 - 1} x_1^{\beta_1} x_2^{\beta_2} x_4^{\beta_4} e^{\beta_5 x_5} e^{\beta_6 x_6} \qquad (4)$$

$$MP_{x_4} = \frac{\partial q}{\partial x_4} = \alpha \beta_4 x_4^{\beta_4 - 1} x_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} e^{\beta_5 x_5} e^{\beta_6 x_6} \qquad (5)$$

In this formulation, the level of marginal product is dependent on the level of other inputs. For example, the expected marginal catch from using more traps depends on rounds per week, x_2, and weeks fished, x_3. Traps per firm is the principal unit of effort. Consequently, the following discussion concentrates on this variable. Influences of x_2, x_3, and x_4 are ex-

[2] The purpose of including x_5 and x_6 was to adjust for variation in production between individual firms due to biological and environmental conditions. This analysis was not intended to examine different production functions by area. Fishing practices do not vary by area. Consequently, a detailed discussion is not presented for estimates of β_5 and β_6.

amined mainly in relation to their effect on catch per trap, x_1.

EMPIRICAL ESTIMATES

The harvest function presented in equation 1 was expressed in log-linear form, and its parameters and standard errors estimated by ordinary least square methods are presented in equation 6.

$$(6)\quad q = \underset{(1.25)}{4.09}\ \underset{(.110)}{x_1^{.7577}}\ \underset{(.277)}{x_2^{.4399}}\ \underset{(.240)}{x_3^{.3721}}\ \underset{(.136)}{x_4^{.3088}}\ \underset{(.149)}{e^{.4446x_5}}\ \underset{(.165)}{e^{.1306x_6}}$$

The coefficient of determination ($R^2 = 0.9310$) suggests the model explains approximately 93 percent of the variation in landings among fishermen (firms). The numbers in parentheses are the standard errors. Estimated coefficients for x_1, x_4, and x_5 are statistically significant and estimates of the parameters for x_2 and x_3 are statistically significant at the 0.13 level.[3]

Total Landings

Total landings of lobsters by the average firm can be predicted by substituting appropriate data for x_1, ... x_6 into equation 6. Total landings were estimated for number of traps fished ranging from 450 to 1,550 traps per firm. This range is representative of most lobster firms. Variables x_2, x_3, and x_4 were held at their mean levels. Estimates are presented in Figure 1 for each region.

Estimated landings for the base region, the middle Keys, ranged from 7,765 to 19,820 pounds per firm as traps per firm were varied from 450 to 1,550.[4] The estimates are most reliable at around 700 traps (approximately 11,000 pounds) as this number represents the mean level of traps fished by firms in the sample during 1973-1974 season.[5]

A statistically significant difference in landings was not found between the middle and lower Keys regions. However, upper Keys landings are significantly greater than those in the base region by a multiple of 1.5598. Total firm landings increased with additional traps fished but the rate of increase was decreasing. The marginal increase in landings due to additional traps fished, as well as the effects of x_2, x_3, and x_4 on the marginal increases, is of prime importance in economic decision making and is the subject of the remainder of this article.

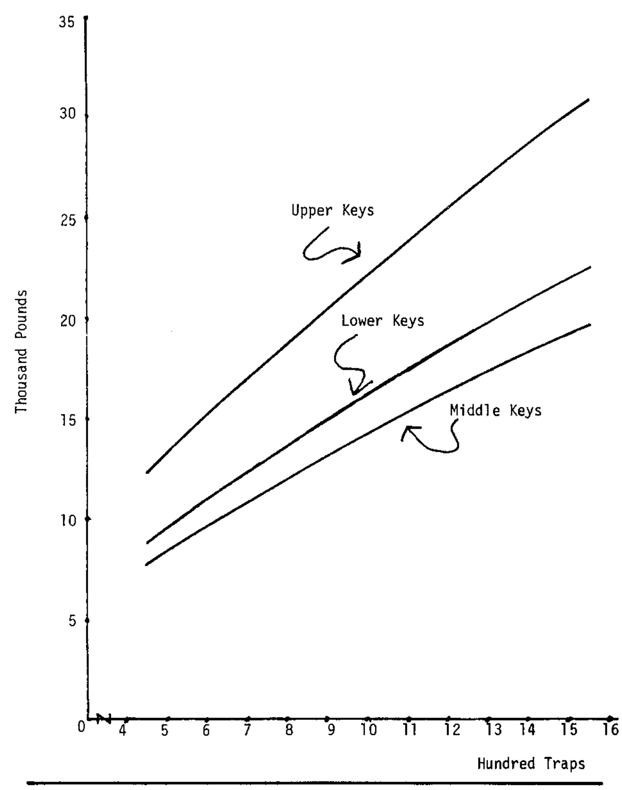
Marginal Landings

The estimated parameters, β_1, is interpreted to mean a 1.0 percent change in number of traps fished per firm will result in a 0.76 percent change in landings. The marginal increase in landings due to the addition of one trap to the typical or average firm with other variables held at mean levels is:

$$(7)\qquad MP_{x_1} = 62.85 x_1^{-.2423}.$$

The second derivative of equation 7 is negative, and thus implies marginal landings per trap will decrease as additional traps are fished by each firm. Declining marginal productivity of additional traps is expected for several reasons. The ability of the captain and/or crew to service each trap adequately as more traps

FIGURE 1. TOTAL ESTIMATED LOBSTER LANDINGS FOR SPECIFIED NUMBER OF TRAPS BY REGION, FLORIDA KEYS



[3] The reader is cautioned not to sum coefficients β_1 through β_6 for an estimate of economies of scale. Coefficients β_3 through β_6 are considered to be effects of time, technology, and geographic space. Expansion of all variables simultaneously probably would not produce the expected arithmetic results because, for example, (1) a limited number of lobsters are available for harvest each season from a given geographic area and (2) some factors of production, such as labor, are not explicitly included in the model.

[4] A few firms are actually fishing 2,000 or more traps.

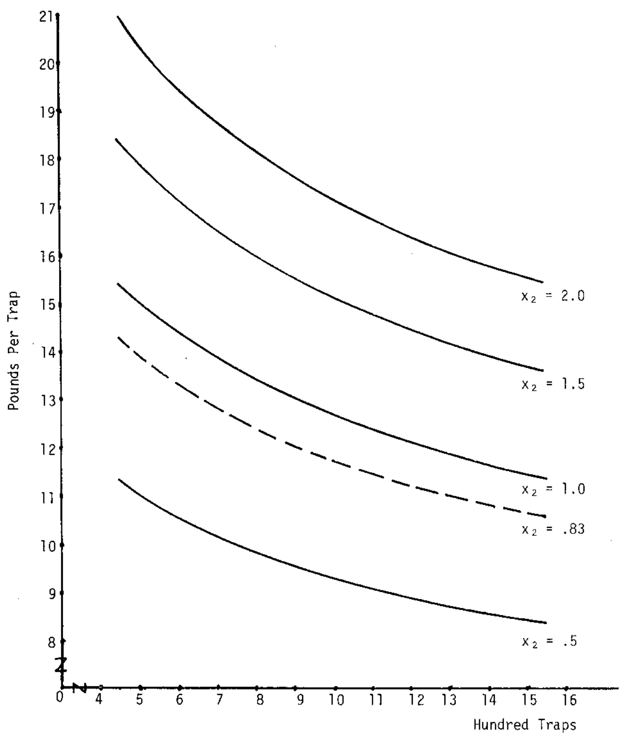
[5] Extreme levels of traps considered are within the range of the data but their effects were estimated mainly for purposes of illustration as the resource would not allow all firms to produce at such levels.

are fished is limited. Moreover, in a given area the number of lobsters is fixed. If a greater number of traps are fished in any given area, catch per trap would be expected to decline.

A comparison of the output elasticities (β_i's) shows the marginal returns from fishing an additional trap are relatively greater than marginal returns from increasing the other effort variables considered.

Marginal products were evaluated with equation 7 for selected numbers of traps per firm. Estimates shown in Figure 2 were developed for the sample data mean levels of x_2, x_3, and x_4 and at alternative levels of x_2.

FIGURE 2. MARGINAL PRODUCTS FOR ALTERNATIVE NUMBER OF TRAPS FISHED ESTIMATED FOR VARYING RATES OF TRAP PULLS PER WEEK (x_2 represents the proportion of all traps pulled per week)



A firm fishing 450 traps and pulling traps at the industry average of 0.83 times per week could expect to land approximately 14 additional pounds of lobsters for an additional trap fished at the same intensity as the previous traps (83 percent of the traps would be pulled per week, the trap would be fished 33.08 weeks of the 36-week season, and the vessel used to fish the trap would be 326 square feet in dimension—i.e., beam × width). As the number of traps is increased per firm, the expected additional product decreases. An additional trap for the average firm with approximately 650 traps can be expected to produce approximately 13 additional pounds per season.

Landings from any given number of traps fished per firm will be increased by increasing the proportion of traps pulled each week (a decrease in set period). The estimate of β_2 shows that as the firm increases its trap-pulling rate by 1 percent, landings will increase by 0.44 percent (equation 6). The additional expected landings from a marginal increase in trap-pulling rate with x_1, x_3, and x_4 held at mean levels is determined by equation 8.

(8) $$MP_{x_2} = 5317x_2^{-.5601}$$

This expected positive marginal effect is illustrated in Figure 2. The marginal product from adding a trap at any trap level is greater as the value of x_2 increases. For example, marginal product of an additional trap for a firm fishing 750 traps is 10.03 pounds if one-half of the traps are pulled each week ($x_2 = 0.5$), which is equivalent to a two-week set period. If the trap-pulling rate, x_2, were increased to $x_2 = 1.0$, all traps would be pulled each week making the average set period one week. In the latter case, the additional landings to an additional trap for a firm fishing 750 traps would be 13.61 pounds, over 3.5 pounds more than during a two-week set period. Further increases in marginal landings from additional traps can be obtained by increasing the trap-pulling rates, as is indicated in Figure 2. However, examination of Figure 2 and the first derivative of equation 8 indicates that marginal returns from increased trap-pulling rates are positive but gradually decline. Again the extreme values for x_2 are illustrated. Trap-pulling rates in the sample ranged from 0.5 to 1.4.

Fishing each trap more often by increasing the number of weeks fished during the season also has a positive effect on the expected catch per trap. The estimated parameter, β_3, indicates a 1 percent increase in number of weeks fished will increase landings by 0.37 percent (equation 6). The expected marginal product from a change in number of weeks fished is calculated from equation 9 for mean levels of x_1, x_2, and x_4.

(9) $$MP_{x_3} = 1093.46x_3^{-.6279}$$

Increases in number of weeks fished shift the marginal product function upward (Figure 3). For example, a firm fishing 750 traps can expect to harvest an additional eight pounds of lobsters if it adds one trap to the total number fished for 10 weeks. If the firm had fished this additional trap 20 weeks, the expected marginal product would have been a little over 10 pounds. Further increases in landings can be obtained by extending the fishing activities to the legal maximum of 36 weeks. However, most of the returns would come within the first few weeks. When the number of weeks fished was doubled (10 to 20 weeks), only approximately two pounds were added to the estimated marginal product per trap. The average number of weeks fished was 33.08 weeks. The declining productivity of fishing additional weeks is due to the fact that the total number of available lobsters is relatively fixed during any one season. Therefore, as additional weeks are fished fewer lobsters are caught in the latter weeks.

The final variable considered is vessel size, x_4. The estimated output elasticity, β_4, indicates a 1 percent change in vessel size is associated with a 0.31 percent change in landings. The expected effect on landings of changing vessel size while holding x_1, x_2, and x_3 at mean levels is determined by equation 10.

(10) $$MP_{x_4} = 558.29x_4^{-.6912}$$

Square footage of hulls in the sample ranged from 80 to 1,045 square feet with an average of 326 square feet (approximately 33 by 10 feet). The increase in landings due to increases in size of craft declines rapidly. For example, using equation 10 to evaluate marginal landings for an additional square foot on a boat or vessel of 80 square feet and 675 square feet gives marginal product estimates of 27 pounds and 4.6 pounds, respectively.

The effect of vessel size on landings per trap is illustrated in Figure 4. Added vessel size shifts the marginal product estimates upward, but for each increase in vessel size the increase in landings becomes smaller. Increased vessel size often is correlated with more efficient gear with which to locate more productive grounds. Also, larger vessels tend to be more seaworthy, thus allowing safe fishing in more turbulent weather.

Optimum Levels of Effort

The marginal analysis indicated that marginal returns in terms of pounds landed were positive but declined with additional units of effort. In addition, marginal returns with respect to one variable are a function of the levels of other effort variables. To determine the most efficient or profitable level of input use, the market value of the marginal products (marginal value product) must be equated with the additional cost of an additional unit of effort. This additional cost is referred to as the "price" or marginal factor cost of a unit of effort. Because of the interdependency among marginal products of the four input variables, optimum levels of each x_1, x_2, x_3, and x_4 should be simultaneously determined. Costs, prices.

FIGURE 3. MARGINAL PRODUCTS FOR ALTERNATIVE NUMBER OF TRAPS FISHED ESTIMATED FOR VARYING NUMBER OF WEEKS FISHED (x_3 refers to number of weeks fished)

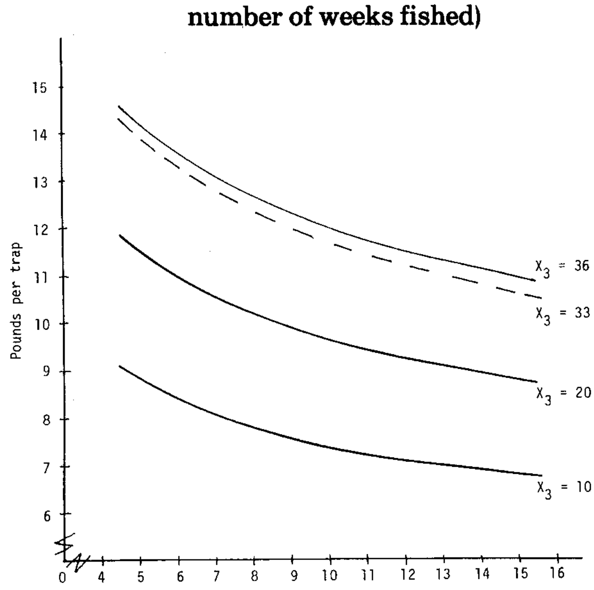
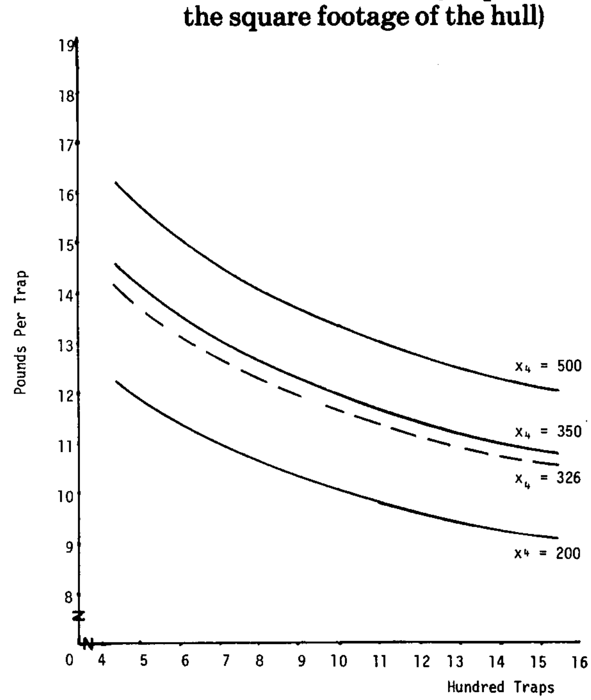


FIGURE 4. MARGINAL PRODUCTS FOR ALTERNATIVE NUMBER OF TRAPS FISHED ESTIMATED FOR VARYING BOAT AND VESSEL SIZES (x_4 represents the square footage of the hull)



or marginal factor costs of each input are required to make this determination. These data are unavilable for several reasons. First, inputs as defined represent a combination of inputs such as labor, wood, and fuel that normally are purchased in the supply markets. Thus, no unique factor prices are obtainable from market data. Second, an attempt to estimate marginal factor costs simultaneously by regressing total cost on levels of input use by multiple regression provided estimates that were highly correlated. For example, the cost of an additional trap fished is a function of the number of weeks fished, x_3, the intensity of fishing effort, x_2, and the size of craft, x_4. These same interrelationships are present when the costs of x_2, x_3, and x_4 are considered.

To provide some indication of optimum levels as well as appropriate considerations for fishermen in applying their own cost estimates a simplified approach was used. Costs per trap, the principal variable, were estimated as a proxy for marginal factor price to allow a determination of the range in optimum trap usage. The effects of other variables and their costs are discussed in terms of optimum levels of trap usage.

Because all inputs used by the firm are translated into the production process through traps fished, total costs per firm can be estimated as a function of a fixed cost component and traps fished per firm. With cost data collected in a 1975 survey of Florida Keys lobstermen [3], equation 11 was estimated to determine an average industry cost per firm per additional trap fished.

$$C = \$1{,}876 + \underset{(2.17)}{\$11.55}\, x_1 \tag{11}$$

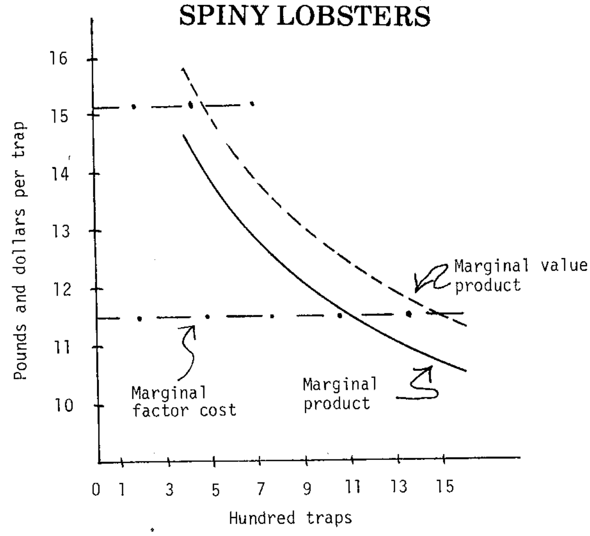
where

C = total cost per firm
x_1 = traps fished per firm.

The coefficient of determination ($R^2 = 0.74$) indicated the number of traps fished per firm explained 74 percent of the variation in total cost among individual fishermen. The constant term, \$1,876, represents fixed costs per firm which do not vary with level of trap use. The number in parentheses is the standard error. The \$11.55 per trap is interpreted as an estimate of the marginal factor cost or "price" of a trap. In this formulation, the \$11.55 per trap represents not only the price of the trap, but also the cost of fishing the trap during the 1973-1974 season.

During the 1973-1974 season, fishermen in the survey reported an average price of \$1.08 per pound for whole lobsters. Marginal value of product was estimated for different levels of trap usage by multiplying \$1.08 times the estimated marginal products per trap which were estimated at mean levels for x_2, x_3, and x_4 and reported in Figures 2, 3, and 4. The marginal product function is shown in Figure 5 along with the marginal value product function.

FIGURE 5. MARGINAL PRODUCT, MARGINAL FACTOR COST, AND MARGINAL VALUE PRODUCT FOR NUMBER OF TRAPS FISHED, FLORIDA SPINY LOBSTERS



The point estimate of the marginal factor cost of fishing an additional trap, \$11.55 is equal to the marginal value of additional lobster landings at approximately 1,475 traps (Figure 5). This indicates the most profitable level of trap usage for the average firm which (1) pulls 83 percent of its traps each week, (2) fishes for 33 weeks of the season, (3) has a craft with dimensions equal to 326 square feet, and (4) has a cost structure which is represented by a marginal factor cost of \$11.55 for an additional trap fished.

The optimum solution in terms of traps fished may be different for individual firms for several reasons. Most likely reasons are differences in marginal factor costs and individual firm deviations in levels of x_2, x_3, and x_4 from the mean levels used for these variables in Figure 5.

The estimated marginal factor cost is based on an expected trap life of three years. It is likely that with increased fishing pressure expected trap life is actually lower or will decrease. If so, marginal factor cost will increase above \$11.55 and thus lower the recommended number of traps fished for an economic optimum, *ceteris paribus*. Another important cost consideration is that the $11.55 is a point estimate. Placing statistical confidence intervals on the point estimate gives a wide range of possible optimum solutions. Because actual costs are suspected to be above the $11.55 estimate, only the upper bound on the cost estimate is shown in Figure 5. Considering the upper bound, the optimum solution may be anywhere between 500 and 1,500 traps per firm, depending on where in this range the individual firm's marginal factor cost is represented.

Firms in the sample which have the capacity to fish or are currently fishing about 1,500 traps usually fish considerably less than the average of 33 weeks. Recall that in Figure 3 the marginal product function shifts downward as the number of weeks fished decreases. This effect would shift the marginal value product function to the left in Figure 5 and thus the optimum number of traps to be fished would be fewer than the approximately 1,500 originally recommended. There are economic reasons which justify fishing less than 33 weeks. Relatively large craft which have the capacity to fish large numbers of traps have the alternative of fishing in other fisheries. For example, the king mackerel net fishery and the stone crab trap fishery are alternatives for larger vessels. For these firms it is more profitable to shift to one of the alternative fisheries before the end of the 33-week season, given their physical capability and the declining marginal product of additional weeks fished (equation 9). If this is the case, the optimum number of traps would be fewer than 1,500.

Similar discussions are appropriate in terms of variations in optimum trap levels due to variations in trap-pulling rates and size of boat or vessel. A reduction in trap-pulling rate (increase in the set period) and a reduction in craft size both have been shown to shift the marginal product function for number of traps fished downward (Figures 2 and 4). Firms fishing less than the mean levels for rounds per week and craft size can expect to have marginal value product functions to the left of the marginal value product function in Figure 5 and thus the optimum number of traps would be lower. Examples of firms for which rounds per week and craft size may be below industry mean levels are (1) part-time firms which pull less than 83 percent of their traps each week because of better income alternatives outside the fishery and (2) firms which have fixed investments in vessels of less than 326 square feet. Firms with larger vessels, however, may optimally fish more than the 1,500 traps for mean levels of rounds per week and number of weeks.

The exact optimum number of traps obviously can be different for each firm because of economic factors arising from variations in levels of rounds per week, number of weeks and craft size. Optimum solutions for numbers of traps for individual firms can be found by substituting appropriate values for x_2, x_3, and x_4 into equation 6 and then differentiating with respect to x_1 as was done in equations 2 and 7. This marginal product function would be evaluated at market prices for lobster and equated to the individual firm's marginal factor cost of an additional trap fished to determine the optimum number of traps.

MANAGEMENT AND RESEARCH IMPLICATIONS

Marginal products declined with increased levels of effort—traps fished, rounds per week, weeks fished, and size of craft—in the spiny lobster fishery. Therefore, there are economic limits to the level of effort by individual firms when costs are considered. "Effort" should not be considered as a single unit because of the interaction and substitution shown among the individual units of effort. That is, combining x_1, x_2, x_3, and x_4 into a single index for the purpose of estimation would limit information necessary for complete analysis of alternative management plans. When each variable is considered separately, the effects of alternative regulatory policies are clear. For example, the same result can be achieved by reducing traps fished or by reducing the season, or some combination of the two.

Additional research on cost of inputs is needed to determine simultaneously the optimal levels of x_1, x_2, x_3, and x_4 when all are variables in decision making. Firms of various sizes can be optimal in terms of number of traps fished at any one time in the industry because of asset fixity, outside employment opportunities, substitute fisheries, and other economic factors. Research on these tradeoffs and alternatives would provide valuable information to individual fishermen as well as fishery management personnel.

Management personnel who have responsibility for a fishery management plan for Florida spiny lobsters should consider several factors pointed out in this research. If one objective of a management program is economic efficiency, maintaining only those firms considerably above the average would be necessary. However, if only these firms were allowed to fish, a severe restriction on the number of firms in the industry would be necessary to prevent overfishing of current or optimum stock levels. The social cost of displacing firms needs to be investigated.

Limitation of the number of traps fished by individual firms often has been suggested as a means of limiting effort. Because relatively large firms (in terms of number of traps fished) appear to be economically optimal, trap limitations may impose economic inefficiencies on the industry.

Continuous monitoring of a fishery management program is necessary. Consideration of Figure 5 supports this conclusion. If the price of lobsters were $1.00 per pound, the marginal product function would be the marginal value product function representative of a market price of $1.00 per pound. The marginal value product function illustrated in Figure 5 is at the 1973-1974 market price of $1.08 per pound. At marginal factor cost of $11.55 per trap, the optimal solution is increased from approximately 1,100 traps at a market price of $1.00 per pound to nearly 1,500 traps for a market price of $1.08 per pound. A relatively small market price change calls for an increase of nearly 400 traps in this case. This finding indicates a need for close monitoring once a program is initiated, and, at least in part, explains the rapid increase in number of traps in recent years.

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