Economic Management Concepts in Small-Scale Spiny Lobster Fisheries

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RESUMEN

La administración histórica de la pesquería está basada en parámetros biológicos. Sin embargo, durante la pasada década ha recibido mucha atención las consideraciones económicas y sociales en relación con el recurso biológico y el impacto en el usuario del recurso. La administración que tenga totalmente un criterio biológico, ha motivado patrones de "sobrepesca económica" en muchas pesquerías desarrolladas. La pesquería de la langosta espinosa de la Florida es un ejemplo primordial de una sobrepesca económica. El exámen del asunto de la sobrepesca económica en pesquerías de pequena escala que aun están en etapas de desarrollo, tales como la pesquería de la langosta espinosa en el Caribe, requiere condiciones adicionales a las examinadas para pesquerías desarrolladas.

Este trabajo describe brevemente los conceptos de administración económica de (1) máximo rendimiento económica, (2) la operación económina de la unidad de pesca, y (3) el impacto en el mercadeo y demanda en la administración de una pesquería en pequeña escala. Se hace énfasis en las necesidades de datos requeridos para el analisis de una pesquería multiespecífica en pequeña escala, en que muchos participantes son pescadores de tiempo incompleto (part-time).

Se examina el máximo rendimiento económico desde el punto de vista de determinar el nivel del esfuerzo pesquero que disminuya la rentabilidad económica que la pesquería genera. Se examina la eficiencia y el esfuerzo máximo de captura de las unidades pesqueras individuales, con atención especial a entidades pequeñas. Se discute el impacto de las decisiones administrativas en el sistema de mercadeo y patrones de consumo en las pesquerías de pequeña escala. Se hacen sugerencias en relación a la alteración de conceptos económicos en la evaluación del impacto de las decisiones administrativas en pesquerías multiespecíficas de pequeña escala, tales como la langosta espinosa en el Caribe. El análisis del impacto en el mercadeo y consumo igualmente variará del aplicable a pesquerías desarrolladas.

Se examina la administración por control directo de esfuerzo, cuotas y por medios económicos tales como licencias, a la luz de pesquerías en pequeña escala y multiespecíficas y/o pesquerías en proceso de desarrollo. Se discuten métodos para estimar el impacto total en el sistema, desde productores a consumidores, como resultado del control sobre la sobrepesca económica. Se de atención especial a pesquerías multiespecíficas y de pequeña escala que estan en proceso de desarrollo y en las cuales la administración de problemas relativos a criterios económicos puedan diferir de los de pesquerías altamente desarrolladas.

INTRODUCTION

Modern concepts in fishery management began evolving around 1850. Initially, management ideas and concepts were biologically oriented with maximum sustainable yield as the norm and management of fish stocks the overriding goal. Economic and sociological issues were recognized much later in the evolution of fishery management policies, and they have only recently been directly incorporated into fishery management.[1] The consideration of economic and social

[1]Direct mandate now exists in the U.S. for consideration of economic and social issues under the Fisheries Conservation and Management Act of 1976.

issues in U.S. fishery management has led to broader management or policy goals which are now discussed in terms of optimum yield. Nielson (1976) recently noted that under the goal of optimum sustainable yield the fisheries manager should emerge as the coordinator and evaluator of knowledge from diverse sources. These sources include fishery biologists, economists, sociologists, politicians, local interest groups, individuals, and other relevant sources.

The main purpose of this paper is to briefly describe the role of economics in fishery management with emphasis on small-scale fisheries. Particular attention is paid to the spiny lobster fishery. However, since it is only one component of most small-scale Caribbean fisheries, the paper also covers fisheries in general. Economic concepts discussed are: (1) maximum economic yield, (2) economic operation of the individual fishing unit, and (3) relationship of marketing and demand to fishery management. Data requirements for economic analysis of a small-scale, multi-species fishery in which many participants are part-time fishermen are discussed. Comments are also offered about the characteristics of small-scale Caribbean fisheries and of the relevance of these economic concepts in managing small-scale fisheries.

ECONOMIC AND INSTITUTIONAL STRUCTURE

Industry expansion or growth takes place when firms in the industry are earning an economic profit. This expansion, through the entrance of new firms, or through individual firms growing larger, will cause greater demands on resources. The increased demand for resources increases their value which in turn increases costs to producers using the resources. At the same time the increased supply of products reduces final product prices. This growth pattern will continue until profits to individual firms in the industry are eliminated due to the falling product prices and increased costs of inputs.

These same economic forces are at work in the fishing industry. However, one primary resource or input (the stock of fish) into the production process is common property rather than private property. The fish belong to no one person, but to all the people in common. They become private property by institutional arrangement or after they are harvested. Thus, no "price" is paid for the fish resource. The normal restraints increased input prices place on industry growth are not fully effective in common property industries. That is, inputs into the fishery will continue to be used longer in the growth process than they would in private property industries. These characteristics can result in a total industry fishing effort beyond the level necessary to produce maximum economic yield. Total industry fishing effort could expand so that maximum sustainable yield is surpassed. These events can occur as the result of the rational economic decisions of individual fishermen. Increased effort by individual fishermen imposes an unaccounted-for cost on all other fishermen. This increased cost due to overfishing eventually curtails production.[2] These factors affect individual expansion. Smith (1975) gives an excellent discussion of this concept from the viewpoint of managing the fishing business. Carlson (1971), Crutchfield (1965) and Scott (1954) all give detailed discussions of the economic theory of common property resources.

[2]However, increased consumer demand can offset the increased costs of overfishing and thus encourage even further expansion of the industry.

Management of a particular stock of fish to achieve economic goals generally imposes some limitation on units of effort devoted to the fishery. It is assumed that individual fishermen or firms in the fishery are profit maximizers. Thus, managed or restricted effort levels and the profit maximizing fishermen imply that fishing participation and investment decisions are made with the objective of creating the highest return to the resources used or employed in the harvesting process. If these resources have better paying alternatives in other fisheries or outside of the fisheries, they will be diverted to that use. Where these assumptions are violated, consideration must be given to modification of management practices based purely on economic concepts. This is probably the case in the Caribbean spiny lobster fishery.

Fisheries of most lesser developed countries usually consist of two sectors, as summarized by Pollnac and Sutinen (1979). One is a small-scale fishery using low-level technology with low incomes and producing fish primarily for local consumption. The other sector is industrial and capital intensive. This sector produces high incomes for a small number of people and the products are primarily for export. The potential for conflict between the two sectors is great where the industrial fishery dominates and negatively impacts the small-scale fishery through competition for the same fish stock and because the by-catch of the industrial fishery dominates the local market.

Pollnac and Sutinen (1979) go on to say that many, if not most, small-scale fishing families also raise crops and livestock and in some areas fishing is viewed as employment of last resort. The local infrastructure including fishery support facilities, institutions and laws may be such that management may need to focus on the resource and harvest level of the small-scale fishery.

Kenny (1978) defines a small-scale fishery as one in which the management and actual fishing process is in the hands of the owner of the capital investment. This is in contrast to fishing operations where day-to-day management is in the hands of a company whose managers may not in fact be directly involved in fishing operations. Kenny (1978) defines subsistence fishing as operations where an individual fisherman spends some significant part of his time in fishing operations geared towards providing family food and cash income from the surplus. Kenny (1978) also indicates that there are comparatively few commercially developed small-scale fisheries in the Caribbean area.

Characteristics of the small-scale fishery are quite important in discussing and analyzing management goals and regulations. Kesteven (1976) gives a detailed comparison of industrial, artisanal and subsistence fishermen of which the latter two fit into the small-scale category. Management comments comparing purely economic concepts with those required for managing small-scale fisheries are made in this paper with small-scale fisheries defined in a similar manner as shown in Table 1.

Spiny lobster fisheries of the Caribbean region may be typically referred to as small-scale, multi-species fisheries. That is, spiny lobsters are for the most part not the target of a directed fishery which uses large vessels and large numbers of traps, such as occurs in the Florida spiny lobster fishery. Caribbean fishing is often done from small boats with small engines or with no power at all. Fishing is often a part-time occupation with the fishermen also deriving income from other occupations. Spiny lobsters are often the by-catch of fish traps rather than the catch of

Table 1. Characteristics of small-scale artisanal and subsistence fisheries.

Characteristic	Description	
	Artisanal	Subsistence
Fishing Unit	Stable, small specialized with no division of labor	Lone operators, or family or community group
Boat	Small; outboard motor	None, or canoe
Equipment	Partly or wholly machine-made materials, operator-assembled	Hand-made materials, operator-assembled
Practices	Minimal machine assistance	Hand-operated
Investment	Low; entirely by operator	Nil
Catches	Medium to low	Low to very low
Productivity	Medium to low	Low to very low
Disposal of catch	Unorganized local sale, significant consumption by operator	Exclusively consumed by operator, his family and friends; exchange by barter
Operator's economic standing	Lowest brackets	Minimal
Social condition	Often separated	Isolated communities

Source: Kesteven (1976)

woodslatted lobster traps. Fishermen sell their catch either directly to consumers or to fish dealers operating in rather unsophisticated market channels.

In the Caribbean region the social and economic structure of the fish catching and marketing system is often such that the fishermen are not pure profit maximizers motivated purely by economic considerations. This dependence affects the fishermen's decision making. Fishermen are often at the bottom of the economic scale and have limited technical skills and capital. Family labor may be involved and uncompensated; thus, costs are often disguised as to their true level. The fisherman may also be economically tied or dependent on a broker or other person in the marketing system for his investment capital.

Miller (1978), in his discussion of the management of small-scale fisheries, categorized management decisions into three categories: (1) those aimed at allocating and conserving the fisheries' resources, (2) those aimed at maximizing the benefits derived from utilizing the resources, and (3) those aimed at maximizing the resources for the future.

The central question regarding management is one of choosing goals. Should the fishery be managed according to biological, economic or social goals? Obtaining maximum benefits from a small-scale fishery requires consideration of other factors in addition to biological and economic factors. Consideration of all factors is necessary to achieve an optimum solution for society. This requires an up-to-date data base of the various types of fishery information. For many small-scale fishery

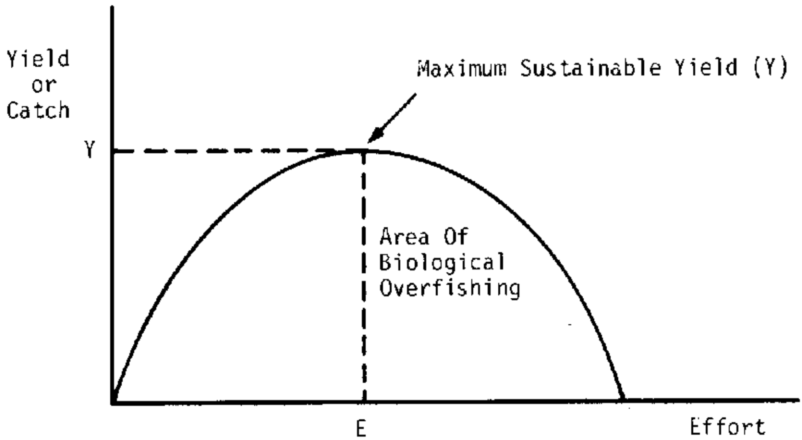

Figure 1. Equilibrium catch levels as a function of fishing effort.

operations in highly localized areas, cultural factors could exert a much greater influence on decision making. In areas where protein is needed, catches may be kept below maximum biological yield to keep supplies more plentiful in relation to expended effort.

Bioeconomic Models

"Bioeconomic" models were developed to explicitly consider economic and biological factors at the same time in making fishery management decisions. They are a recognition that both sets of parameters need to be considered simultaneously. These models are used for aggregate management or management of the total fishery as opposed to analysis of management of individual firms.

Theoretical Considerations. The yield function normally used in bioeconomic models is based on both biological and physical production characteristics. The function is an effort-yield relationship which may be used to describe biologically sustainable production levels for different levels of fishing effort for a stated time period (Fig. 1). Initially, as effort increases total sustainable yield increases. At some effort level (E), there is exactly enough mature progeny left in the system to replace the parent stock and still yield a production which is the maximum sustainable yield (Y).[3]

Multiplication of product price times the yield function generates the economist's total revenue function (Fig. 2).[4] The total revenue function simply represents the amount of revenue received in the industry from sales resulting from specified levels of effort. Total industry costs incurred for various units of effort also increase as

[3]For the spiny lobster fishery in which there is a minimum size limit and protection of berried females, it is often argued that the yield curve approaches the maximum yield asymptotically. At the upper range, increases in effort cause very small increases in yield and total yield will not decrease due to the protection afforded the fish stock (Williams and Prochaska, 1977).

[4]In this discussion product price is assumed fixed to simplify the discussion. Price could be expected to be inversely related to volume caught for large changes in effort.

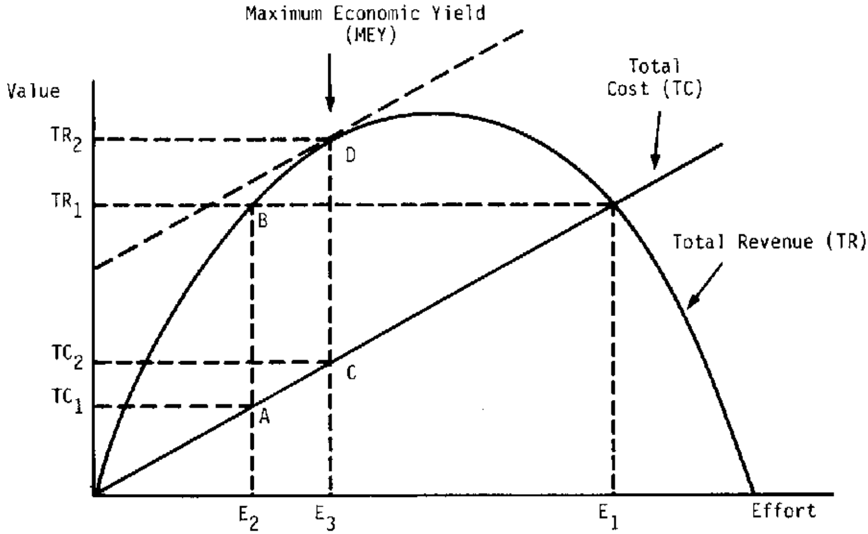

Figure 2. Total and net revenue yield levels for various levels of fishing effort.

effort increases (Fig. 2).[5] As long as the revenue curve (TR) is above the total cost curve (TC) for given levels of effort the industry is earning a profit. If all costs including the owner's opportunity costs are included in total costs, the profit is defined to be economic rent. As long as positive levels of economic rent are earned, more entry and effort into the fishery can be expected. In an unregulated fishery entry will occur until total effort is equal to E_1. At this point, no economic rent is being earned and thus no new entry into the fishery is encouraged. Notice that at effort levels E_1 and E_2 the same amount of total revenue is generated. At E_2 total economic rent generated is defined by the area TR_1TC_1AB. Maximum economic yield (MEY) is generated at effort level E_3 and is defined by the area TR_2TC_2CD.

MEY is often proposed as one goal for fishery management, not because of the economic rent generated but because of the economic rent which will be earned by the resource (fish stock).[6] To achieve this goal, restrictions on effort are necessary because without artificial constraints the fishing industry operating at any level below E_1 will move toward E_1. This is particularly true in the case of rapidly rising product prices. Increases in consumer demand lead to higher product prices. Increasing scarcity of the resource from overfishing also adds to increases in product prices which then encourage even further increases in effort. It should be pointed out that limiting effort to achieve this economic objective may cause other economic problems. Most management programs to restrict effort have attempted to limit the efficiency of individual firms which conflicts directly with the proper "business

[5] The cost function is linear when expressed as a function of inputs (effort) unless the use of additional units of effort raises the price of inputs. This does not generally occur for small-scale, gradual increases in effort. Costs include both fixed and variable costs plus a return to management, labor and investment at least equal to the returns these inputs could earn in their next best alternative.

[6] It is assumed the economic rent would be collected from the industry and distributed to the common owners of the resource.

management" objectives of the individual firm. Prochaska and Baarda (1974) give a detailed analysis of this process.

Empirical Models. Bioeconomic models are usually estimated by first relating yield to corresponding fishing effort over a period of time or production seasons, as discussed by Prochaska and Cato (1980). Yield is usually measured as volume landed or caught. Effort, in the theoretical literature and in many applied statistical models, has been measured as an index of such inputs as fishermen, vessels, or gear units. This index allows for adjustments in technology, scale of operation, and others. For example, the number of fishermen may be the basic unit of effort, but this effort unit may change through time because of changes in the number of gear units used per fisherman. The technological efficiency of each unit of gear may also change over time. That is, new or different trap styles may "catch" better than previous styles. Indexing inputs adjusts for these factors so that "effective" units of effort are measured through the time period of analysis. An alternative method for adjusting the effort variable, or variables, is to include the individual items in a statistical regression model. The regression procedure essentially accomplishes the same thing as indexing or standardizing units of effort. However, the latter approach has the advantage of being more directly applicable to an analysis of management programs since specific variables analyzed are those subject to regulations and are based on theory applicable to the fishery.

The estimated parameters in the bioeconomic model which show the effect of different levels of effort on catch are usually statistically confounded. This means that the parameters reflect both (1) the effects of effort on catch resulting from stock level changes which result from fishing effort and (2) the returns to proportion[7] reflected in any production process. Ideally, variables measuring stock in each time period would be included so that the separate effects of effort on landings could be determined. Unfortunately, these data are not normally recorded on a continuous basis. Environmental variables such as water temperature are often included as proxy measures for the stock variables. Water temperature reflects to some degree environmental conditions that affect the stock as well as sea conditions for some fisheries, particularly spiny lobster.

Empirical bioeconomic models, in combination with industry cost and revenue functions, have been used in several studies. Williams and Prochaska (1977) estimated the maximum economic yield in the spiny lobster fishery of Monroe County, Florida (Florida Keys). Using 1973 prices, the profit maximizing solution was 795 traps per firm (boat) with 213 firms in the industry. Maximum economic yield was 5.8 million pounds.[8]

This solution implies that a removal of 186 firms in the industry would have been necessary to achieve maximum economic efficiency. However, each remaining firm would fish considerably more traps. This reorganization would decrease industry costs to $2.36 million from the 1973 cost level of $2.73 million. Savings measured in reduced costs are $.37 million. This savings of approximately 14% must be compared to the social cost of displacing 186 firms from the industry before an

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[7]Returns to proportions refers to increasing or decreasing production per unit of variable input due to some other fixed inputs used in the production process.

[8]This work is currently being updated to a 1979 solution by Fred Prochaska and Walter Keithly, University of Florida.

"optimum" yield can be determined. In addition, the redistribution of income must be considered. Predicted profits would be $18,350 per firm compared to $6,677 before the reorganization of the industry. Fishery managers would be faced with the question of determining if any part of $18,350 in profits was economic rent and, if so, how the rent would be taxed away or returned to society.[9] The ideal situation would be effort controls before the maximum economic yield level of effort is exceeded.

Problems With Caribbean Application. Estimation and use of a bioeconomic model would probably present more "problems" in a small-scale, multi-species fishery such as the overall Caribbean spiny lobster fishery than in a more highly developed and directed fishery such as the Florida spiny lobster fishery. For most of the Caribbean fisheries, sufficient catch and effort data and economic data have not been maintained on a time-series basis in adequate form for a sufficient time period to allow model estimation. Effort going into the Caribbean spiny lobster fishery is also of such varying technology as to cause indexing problems. For example, in the Florida fishery almost all effort going into the fishery is represented by a similar style wooden slat trap. In the Caribbean, effort is divided by varying degrees into that represented by wire fish traps, wooden traps, and through diving. Some effort is directed toward lobsters, but in many cases the lobster catch is considered as a secondary fishery or a by-catch. Actual effort directed toward lobsters would have to be determined and indexed. Next, accurate dockside price data associated with the same observed catch levels would be necessary.

Industry level cost data would be necessary to generate an industry cost function. As pointed out earlier, many cost items may be disguised and jointly incurred in multiple species operations in small-scale Caribbean fisheries. The estimation of a representative lobster cost function would be difficult. For example, what part of the fisherman's total cost of fishing should be attributable to spiny lobsters when lobsters represented only one of the species caught? What are the real costs of fishing when nonpaid family labor may be involved in the fishery?

In the event management personnel did use maximum economic yield as a management criterion, what type system would be acceptable in "taxing away" economic rent? The administrative and social costs of this reallocation process might far outweigh the benefits of such a system. In the case where many part-time fishermen are involved and where spiny lobsters are only one revenue source resulting from a multi-species catch, many questions need to be answered with respect to effort limitations. That is, should effort be limited equally across both part-time and full-time fishermen, or should part-time fishermen be limited before any limits are placed on full-time fishermen?

Small-scale fisheries should also be viewed from their role in employment. Since unemployment is a condition often associated with small-scale fishing, employment levels beyond those that maximize economic efficiency may be a more useful goal. This may also mean better fish supplies for the fisherman's family and for local consumption.

It should be clear that economics is only one of the social sciences which need to be considered for effective management. Planned management of any sector of an economy will be maximally effective if proposed measures are instituted with an

[9] This cost function did not include a return to the owners' labor, management and capital. Thus, the total $18,350 would include this return plus any economic rent over and above a fair return to labor, management and capital.

understanding of the target population's attitudes, beliefs, and values towards the affected occupations. This will help to negate potential conflicts and disagreements. Social and cultural attributes are often a main cause of management program failure.

Many authors have discussed the importance of a thorough understanding of social and cultural factors in the success of development projects. The same importance level of these social and cultural factors is associated with fisheries management. Articles discussing in detail the social and cultural characteristics of small-scale Caribbean fisheries include Pollnac (1977a, 1977b, 1977c, 1977d, 1978), Langberg (1979) and Poggie (1979a, 1979b, 1979c).

Firm Production Models

Theoretical Considerations. The production function for the individual firm or vessel provides a basis for the analysis of costs, revenues, and resource allocation for that firm. The production function for the firm defines the physical relationship between a firm's input of resources and its output of product per unit of time. The law of diminishing returns describes the general direction and the general rate of change which the firm's output takes when the input of only one resource is varied. That is, if some resource is increased by equal units per unit of time while the inputs of other resources are held constant, total product may increase; but beyond some point, the resulting increases in output will become smaller and may decrease. The firm will maximize total product by distributing its cost outlay among different resources in such a way that the marginal physical product of a dollar's worth of one resource is equal to the marginal physical product of a dollar's worth of every other resource used.

The firm with profit maximization as its motive will examine the quantities used of all its resources with regard to their effects on the firm's total revenue, total costs, and hence, profit. If larger quantities of a firm's resources will add more to total revenue than total costs, units of the resource will be added (or vice versa). The profit maximizing firm with unlimited resources adds units of resources to the production process until the revenue earned on the last unit of resource equals the cost of employing that resource. Thus, units of resource will be added until the value of marginal product of that unit of resource just equals the cost or price of that unit of resource.[10] The value of marginal product is determined by multiplying product price times the amount of product produced by each added unit of resource.

Empirical Models. Prochaska and Williams (1978) examined the productivity of individual inputs of the typical Florida spiny lobster firm. Landings per vessel were examined as a function of traps fished per vessel, proportion of total number of traps pulled each week, number of weeks fished, vessel size and fishing location. The marginal productivity of each of the inputs was examined. This research indicated that a 1% change in the traps fished per vessel caused a 0.76% change in landings and that the marginal productivity of each trap declined with additional traps. The marginal returns from fishing an additional trap were relatively greater than marginal returns from increasing the other effort variables considered. One percent changes in proportion of total number of traps pulled each week, number of weeks

[10]In a common property resource where there is no price associated with the raw fish input, logical expansion by the individual firm beyond the appropriate industry level or effort may occur as long as final product price expands.

fished and vessel size were associated with 0.44, 0.37 and 0.41% changes in landings, respectively, and each demonstrated declining marginal productivity.

Traps were used as a proxy for measuring the transfer of effort into the fishery and in determining the most profitable level of input use. For the average firm, the cost of fishing an additional trap was equal to the value of the marginal product of that additional trap (lobster price times marginal product of the additional trap) at approximately 1,475 traps. This indicated the most profitable number of traps for the average firm. The average firm pulled 83% of its traps each week, fished for 33 weeks of the 36-week season, had a craft with dimensions (length times width) equal to 326 ft^2, and had a cost of fishing an additional trap equal to $11.55.[11]

Problems With Caribbean Application. Firm production models are quite useful in evaluating the effects of management decisions on the individual fishing firm. For example, the effects of limiting the number of traps used in the overall fishery on the individual firm could be determined. However, as discussed in the section on bioeconomic models, a number of problems may be encountered in attempting to estimate firm production models for small-scale, multi-species fisheries such as the Caribbean spiny lobster fishery. Data obtained from individual fishermen may give biased cost and resource price information, due to the value systems of the small-scale fisherman who has few alternatives and the way in which real costs are perceived. Physical limitations such as boat size may also cause resources to not be allocated in the most economically efficient manner. It may also be necessary to consider species other than spiny lobsters in analyzing the effect of any regulations on lobster fishing. That is, restrictions on lobster fishing might affect the economic returns derived from fishing activities supplemental to lobster fishing. In small-scale lobster fisheries, simple cost and returns budgets may be more useful than firm production models in advising fishermen of the most profitable fishing practices and/or analyzing the impact of any management regulation.

Marketing and Demand

Lampe (1978) indicates that demand analysis for fishery products in developing countries has long been neglected because officials in charge of development have felt no need to assess demand and the data for demand analysis have not been available. Lampe (1978) argues that statistical systems should include the requirements for demand analysis. The same argument should be advanced for these data for management reasons.

Marketing and demand data and analyses are essential for effective management. Management of fisheries usually changes the quantities moving into the market. As these quantities change, the prices change. Once prices change, the economic targets change. Thus, demand or price functions must be considered simultaneously with production and cost functions to arrive at MEY solutions.

Marketing and demand information also is the basis for determining economic impacts of alternative management programs. Price equations are used to determine the value of the fishery for different levels of output. Market channel and structure studies help identify the individuals affected. For areas where lobsters are locally marketed and sold, less sophisticated market data will probably be sufficient rather than demand models.

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[11]This work is currently being updated to 1979 levels by Fred Prochaska and Walter Keithly, University of Florida.

Data Needs[12]

The desire for an adequate data base and supportive research studies most often is greater than the level of funds available to support data procurement and the research activity. The suggested data base and research needs outlined represent the optimum system for such an area as the Caribbean (Table 2). Most data on spiny lobsters would be collected in concert with data collection efforts of other fisheries. The discussion in this section concerns collection of economic data for all species. Data collection and research priorities should be set so that budget allocations could be made under budget constraints.

Data Problems Particular to Caribbean Area. One major problem in studying the data needs of an area such as the Caribbean involves the number of political subdivisions (countries) involved in spiny lobster production. Many biologists argue that the Caribbean is an "open system" regarding larval dispersal patterns and recruitment stock distribution. If so, management policies of one country affect the yield or productivity of another country, and thus they also affect estimates of bioeconomic and firm production models. The economic conditions of the spiny lobster fisheries of each country are also affected by conditions outside the region since large numbers of lobsters are exported. Thus, there is a major need for coordinated management, data collection, and research programs of the many countries.

The question of jurisdictional rights is also important to small-scale fisheries, even though most fishing is done in coastal waters. Data and research boundaries should be consistent with fishery boundaries. Extension of fishing boundaries to 200 miles prevents the more industrialized nations from competing with the small-scale fishermen and provides a revenue source through licensing fees to the underdeveloped countries. This also gives countries the ability to manage their fisheries through what might be a different set of economic objectives.

In the following sections data needs are outlined and discussed briefly. Then, the research studies that would be helpful in making economic decisions with regard to fishery management and additional uses of the data base are discussed. Research studies are based on primary data collected during studies and with data provided from the ongoing data base suggested in the following section.

Production Statistics. LANDINGS—Production or landings statistics are most useful when reported on a monthly and annual basis. This allows for trends that can be analyzed both seasonally and cyclically. Both pounds landed and the value of the catch are important for use in economic analysis.

EFFORT—Complete measurement of effort requires data for several individual variables. The number of boats and vessels classified by length, width, tonnage and propulsion type and size enables determination of the capital investment and of the harvesting capacity in the fishery. Documentation of gear units by specific type deployed in the fishery is also essential. These gear units must be classified by craft and catch.

Finally, the total human effort or man-days required to harvest the catch provides another necessary measure of effort. Fishermen should be reported as full-time and

[12]This section on data needs is patterned primarily after economic data needs sections of the spiny lobster (February, 1978 draft) and shallow water reef fish (July, 1979 draft) draft management plans of the Caribbean Fisheries Management Council. These sections were originally authored by the authors of this paper.

Table 2. Data requirements for an effective economic research data base and suggested research needs for the Caribbean area small-scale, multi-species fishery

Data Requirements	Frequently needed
I. Economic Data Base Needs	
A. Production Statistics	
1. Landings	
a. Pounds	annually
b. Value	and monthly
2. Effort	
a. Boats and Vessels	
i. number	
ii. size by length	annually
iii. classified by motor size	
b. Fishermen and helpers	
i. full-time	
ii. part-time	
iii. number of helpers	annually
iv. monthly and annual fishing rate	
c. Gear Units by Specific Type	
3. Cross Classification of Landings and Effort	annually
B. Market Statistics	
1. Employment	
a. Number of Wholesalers, Processors, Middlemen, Importers and Exporters	annually
b. Employment in Marketing Sector	annually
2. Prices	
a. Fishermen Level	
i. Prices received from wholesalers	annually
ii. Prices received from retailers	and monthly
iii. Prices received from consumers	
b. Wholesale Level	
i. Price received from retailers	annually
ii. Price received from consumers	and monthly
c. Retail Level	
i. Price received from consumer	annually
d. Import and Export Prices	and monthly
e. Processed Product Prices	annually and monthly
3. Volume	
a. Fisherman Level	
i. Volume of sales to wholesalers	annually
ii. Volume of sales to retailers	and monthly
iii. Volume of sales to consumers	
b. Wholesale Level	
i. Volume of sales to retailers	annually
ii. Volume of sales to consumers	and monthly

Table 2. Continued.

Data Requirements	Frequently needed
c. Retail Level	
i. Volume of sales to consumers	annually
d. Volume of Imports and Exports	and monthly
i. Import sales to various market levels	
e. Volume of Processed Product	
II. Research Needs	
A. Production	
1. Costs and returns budget for each major fishery by gear type and size of operation	Every 3-5 years
2. Industry and firm production and cost functions	annually
B. Consumption and Demand	
1. Demand equations by major fisheries	Every 3-5 years
C. Marketing	
1. Description of product flows	Every 3-5 years
2. Descriptive study of marketing and processing activities	Every 3-5 years
3. Feasibility of new methods	As Needed
4. Analysis of data base	annually
D. Social and Economic Profile of Fishermen	Every 3-5 years

part-time fishermen. Helpers (number) and the monthly and annual fishing rates are also important.

CROSS CLASSIFICATION—Landings data should be cross classified with effort variables on an annual basis for analysis of the relationship between catch and effort. Care should be exercised that the data are reported in the same manner each year to provide continuity in the data. This continuity allows for time series econometric analysis of catch-effort data after sufficient years are reported.

Market Statistics. EMPLOYMENT—Annual reporting of the number of wholesalers, processors, middlemen, importers and exporters provides information on the size, structure, economic importance and the growth of the marketing sector. Reporting of the number of employees provides a similar measure and also allows a measure of efficiency when annual output rates for employers are recorded.

PRICES—Price data are necessary in order to analyze seasonal and cyclical price variations at different marketing levels. Price data permit the estimation of market margins and the effect on price of changes on the volume harvested and marketed. Price data should be collected at the fishermen, wholesale, and retail levels by product forms, such as fresh and processed. Finally, import and export product prices allow the determination of how domestic market prices compete in the international markets.

VOLUME—Quantities marketed should be reported at the same levels at which price data are obtained. This allows for analysis of the relationship between price and quantity. Volume data also allow the determination of the economic structure, conduct and performance of the marketing system. Knowledge of product flows facilitates market development where the resource base is adequate for market expansion. In the event of problems with the resource base, product flow data would allow determination of which segments of the market would most likely suffer hardships.

Methods and Problems in Data Collection

Collecting economic data in small-scale fisheries that can be used in formulating management practices provides a challenge to any management agency. Not only must economic conditions be surveyed, but social and cultural considerations must be recognized not only in the type of data collected, but in the way it is collected. These considerations must also be made in collecting biological and environmental data. Pollnac and Sutinen (1979) give an excellent discussion of the information systems paradigm in developing data on and from small-scale fisheries.

Pollnac and Sutinen (1979) present the argument that, in reality, the fishery and its related sectors is vast and complex. It is composed of several components which are related to other non-fishery sectors. Because of this, they feel any management system (or development) should not concentrate on the complete system, but concentrate on the closely related resource and capture sectors of the small-scale fishery. That is, concentrate on the biological stock and fishermen harvest level. To quote Pollnac and Sutinen (1979):

> The part of reality focused on involves both the fishery resource and its habitat and man's exploitation of the resource. Much like the fishery resource, man's behavior is conditioned by his environment, an environment that consists of social, cultural, economic and other related elements. It seems clear, therefore, that in order to provide useful, reliable information to decision makers a stock assessment information system should take into account all of these elements of reality, as well as the nature of the decision-making process.

The implications of such a bio-socio-economic approach may be quite significant. This implies (1) an integrated, interdisciplinary conceptual framework, (2) a joint effort to systematize the collection and analysis of data on the behavior of the fishery resource and the human sectors, and (3) a study and appreciation of the decision-making environment that exists. These seem to be some of the conditions necessary for an effective information system.

Pollnac and Sutinen (1979) also comment on the problems of obtaining data for stock assessment in small-scale fisheries. Their comments also hold for obtaining economics data. The basic data, particularly on catch and effort, will have to be obtained from local fishermen. In this regard: (1) The fisherman is the only one who really knows his catch and effort. (2) It is necessary to determine the attitudes, beliefs, and values regarding the data being collected. (3) Interaction is best with small groups rather than individually. (4) It is necessary to make the fishermen and interviewers aware of what the data are to be used for to avoid incorrect beliefs. (5) The data collectors should have sympathy with, identify with, and have credibility with the fishermen. (6) Methods of communication and communication channels may vary among groups of small-scale fishermen.

The authors in general agree with the ideas and arguments presented by Pollnac and Sutinen. However, their recommendations are more applicable to primary research data which does not need to be collected on a continuous basis. Beliefs and values are rather slow to change and therefore do not need to be assessed each year. Also, once credibility with fishermen has been established continuous contact is not necessary. Catch-effort data may be more efficiently collected through means other than with direct continuous contact with fishermen. Furthermore, to concentrate only at the stock and fishermen level may be appropriate for the initial stages of long-term management, statistical and research programs. However, in the long run, neglect of data from the market system will leave unanswered many of the questions raised in this paper and by management authorities.

Some data are most easily collected when the fishery resource or product passes through a $mall number of handlers or dealers in an established marketing chain. When such a marketing chain exists, few interviews are necessary because data can be collected from a relatively small number of dealers. In the absence of an established marketing system, the initial landings and value data must be collected at the fishermen level. This is the case in many small-scale Caribbean lobster fisheries.

Since the number of fishermen is large compared to the number of individuals in any level in the marketing system, reliance on voluntary reporting by fishermen is sometimes necessary. Reporting can be made mandatory, but lack of manpower to monitor reporting makes compliance difficult to enforce. In many small-scale fisheries the cost of data collection represents a fiscal outlay too large to justify. A voluntary reporting system could be augmented with a stratified sample of fishermen. A relatively small labor force in the statistics office of the appropriate governmental regulatory agency could carry out the sampling. Once production classes (by levels of activity, size, and gear type) are determined for stratification, individuals can be selected at random for monitoring of production and sales for selected reporting periods. The entire catch of these individuals would be monitored monthly, bi-monthly, quarterly, bi-annually or annually to provide landings and value data. These data could then be projected to the total fishery. From these samples, adjustments in the voluntary and often simple recall data reported could be made for the total fishery. Without an adequate and reliable data base a fishery cannot be successfully managed with sound economic, social or biological scientific principles.

Research Needs

Fulfillment of the research needs outlined in this section requires both maintenance of an ongoing data base and the collection of primary data at the time research studies are conducted. The annual research needs outlined (Table 2) require an ongoing data base. Research needs of a less frequent nature require some primary data in addition to using data from the annual data base.

Production. Research concerning the production or harvesting of a fishery resource is concerned with both production cost and returns budgets and more sophisticated industry and firm production and cost functions. Cost and returns budgets are useful when developed for each major fishery by gear type and size of operation. For example, spiny lobster are taken primarily by fish pots and lobster pots. If the fishery were comprised of basically two sizes of boats, a production budget should be developed for both sizes of boats using each kind of pot. The budget would represent the average cost and returns for boats of a given size and/or class.

Cost and returns budgets show profitability of alternative fisheries and fishery practices. They also provide economic information on sales and purchases which can be used as an indication of the economic contribution made by the fishery to the area economy. Budgets also provide an economic data base for determining the economic consequences of alternative management programs. For example, a budget would allow a partial analysis of the effects on profit levels if the number of traps used were limited or if fishing were allowed only during certain months.

Econometric analysis of industry and firm production and cost functions is only possible after enough years of data collection. Firm production and cost functions answer basically the same questions as costs and returns budgets but they allow for consideration of production on a continuous basis for a wide range of effort levels. Industry production and cost functions allow the determination of maximum economic yield levels in a fishery. These functions are also used to analyze changes in industry harvest or catch levels resulting from management decisions affecting fishing effort through trap limits, fishing days or seasons, or other controllable variables.

Consumption and Demand. Demand or price response equations show prices that can be expected for different volumes of lobsters or other fish placed on the market. Changes in price resulting from population and income changes are also determined with demand equations. Effects on both domestic consumers' consumption patterns and the import and export markets for fish and lobsters resulting from management decisions could be analyzed.

Marketing. Studies that describe the product flows through the marketing system would draw heavily on the ongoing data base. This research would point out market inefficiencies and determine the potential effect of various catch levels on each segment of the marketing system. Feasibility studies of new marketing methods and alternative product forms will aid in the development of the domestic fishing industry.

Social and Economic Profiles. Information developed in social and economic profiles of fishermen is necessary for determining the optimum yield of the fishery. Typical profile data are education, full or part-time fishing employment, incomes earned outside fishing by fishermen, job opportunities outside fishing, fishermen's personal goals and objectives in fishing, the level of subsistence fishing and other economic and sociological considerations. These are important in decreasing the consequences of alternative management programs. Profile data can be used to modify goals resulting from research based strictly on economic efficiency and/or biological parameters. For example, fewer fishermen might be able to harvest the same volume of lobster or fish using more efficient methods, and incomes would be higher to these individual fishermen. However, a large number of fishermen may have fishing as their only income source because of a lack of job skills or a lack of alternative employment in the local economy. Social and economic profile studies allow these factors to be given weight in management decisions.

ECONOMIC CONTROLS ON OVERFISHING

Economic methods for controlling effort in a fishery can be grouped into three broad classes. These are controls that (1) limit the number of fishing licenses, vessels or gear; (2) allocate the resource using quotas among fishermen; and (3) impose a tax or fees on the resource users. Discussions of these control measures can be found in Anderson (1977a, 1977b) and Christy (1975) as well as a number of other sources. They are briefly discussed in the following sections.

Management of fisheries strictly by economic criteria has not met with overwhelming acceptance in even the most developed fisheries. Legal challenges, social equity issues and questions regarding income redistribution have always been the challenging issues. All of these challenges have merit. These same issues will certainly be confronted in small-scale Caribbean fisheries if only economic concepts are considered. Perhaps more important will be the social equity and income distribution issues.[13]

Limiting Vessels and Gear Through Licensing

Licensing the basic units of effort in a fishery is probably the simplest management technique used to control effort. In spiny lobster fisheries, an example is to control the number of traps or pots used in the fishery. For political and social reasons this management tool is usually instituted when needed by first licensing all existing units of effort in the fishery. Effort is then gradually eliminated from the fishery by retirement of individual license holders. If the licenses are transferable the value of the license would probably increase through time and the level of effort would not be reduced through retirement. Inefficient producers would, however, be eliminated from the industry if licenses were transferable through the market. This, however, would result in effectively more units of effort since only the most efficient would remain. In addition to replacing inefficient fishermen with efficient fishermen, the remaining fishermen could also introduce new technology into the fishery and further offset any gain in effort control. The licensing scheme would be the most politically acceptable, but probably would not meet the criteria of biological effectiveness and economic efficiency.

These management problems would be present in a small-scale fishery such as the Caribbean spiny lobster fishery in addition to other problems particular to the area. Basic units of fishing effort are wire fish pots, Florida style wood slat traps and diving. Several types of effort would have to be licensed. The impacts of limiting the gear units would be dependent on vessel size, full-time versus part-time fishing status, and other variables. Equitable limits would be necessary for each type of effort (and thus fees) which would present an administrative problem. Where spiny lobsters are a by-catch rather than a directed fishery there would be additional management problems.

[13] Problems relating to dealing with a large number of countries or management units were discussed earlier and will not be discussed in these sections.

Quotas

Quotas do not directly provide a means for controlling effort, but leave the fishermen to control their individual effort in meeting their quotas. This technique provides a direct control on annual or seasonal harvest. In addition, each fisherman could minimize costs of producing the allocated quota. However, to attain economic efficiency in the long run where economics of scale are considered, fishermen would have to be able to sell (or lease) their quotas. The ability to transfer quotas allows the individual firms to become of sufficient size to be economically efficient. There would probably be fewer firms in the industry. To be totally equitable to society this method would also have to be combined with taxes or fees to allow for the extraction of economic rent in the fishery. Making the initial allocation would be difficult.

In Caribbean small-scale fisheries a quota system might lead to the concentration of capital in the fishery. If economies of scale exist, a few larger firms could efficiently bid away the quotas. Small-scale fishermen would be tempted to sell their quotas to the larger operators for short-term capital gain. Once sold, these fishermen would probably not have the capital necessary to purchase quotas to again enter the fishery. The consequence of this situation might be magnified in the case where part-time fishing was predominant and partial family incomes were dependent on the fishery. The long-run social consequences of no longer being able to fish would also be potentially damaging to the fishermen and their community social structure.

Taxes and Fees

Controlling entry by charging a tax on catch or a fee on inputs such as vessels and gear would extract economic rent from the fishery and would encourage marginal fishermen to leave the fishery. Those unwilling or unable to pay the tax or fee would not enter the fishery. The amount of effort control would depend on the level of the tax or fee. The level could be adjusted to account for changes in the supply and demand for the fish. A fully applied tax or fee would extract and return all economic rent to society. This system is probably the least politically palatable and, if instituted in an already overfished and depressed fishery, would cause short-run hardships on the fishermen. The consequences in a small-scale Caribbean lobster fishery of the imposition of a tax or fee were discussed under the licensing option.

EFFECTIVENESS OF ECONOMIC MANAGEMENT

Evaluating management concepts requires consideration of economic efficiency, biological effectiveness, income distribution and political feasibility. Management must consider not only the inputs into catching the fish but also those going into administration, research and enforcement. Changes in supply, demand and technology must also be considered. Biological effectiveness deals both with the yield level and the problems of interrelated fisheries. Interrelations that cause problems include conflicting values (commercial versus recreational), the value of fishing as a way of life and multi-species fisheries. Equitable distribution of income considers society as well as the individual fisherman. Society can argue that at least the cost of administering and managing a fishery should be taxed from the fishery. Political feasibility is concerned with the acceptance of a management scheme by those being regulated as well as joint acceptance by all governing bodies throughout the range of the fishing stock.

Management for economic goals is best accomplished (but seldom instituted) before actual fishing effort is greater than that necessary to achieve the maximum economic yield. In this case effort does not have to be reduced but simply limited at the appropriate point. This situation might exist in a developing fishery and the political problems of "decreasing effort" would be much less apparent.

SUMMARY

Economics has a role in fishery management. However, special attention must be given to the application of economic concepts in small-scale fisheries such as the Caribbean spiny lobster fishery. Economic concepts of importance to fishery management can be categorized into the areas of maximum economic yield, operation of the individual fishing firm and the relationship of marketing and demand to fisheries management. This paper has attempted to relate the application of these concepts to small-scale fisheries and point out data needs and problem areas which must be satisfied.

The estimation and use of bioeconomic models in small-scale, multi-species fisheries of the Caribbean region may present many problems. Data are lacking and technology is of such varying levels that indexing true effort levels in the Caribbean fisheries is difficult. Estimation of cost functions will also be difficult due to the measurement problem of defining "actual costs" in a small-scale fishery. Maximizing employment may also be a goal in management. This conflicts with the strict application of the concept of maximum economic yield in defining the most efficient employment level; however, sociological considerations are extremely important in managing small-scale fisheries.

Similar problems exist in estimating empirical firm production models for small-scale fisheries. Data obtained from individuals may give biased cost and resource price information due to the value systems of the small-scale fishermen who have few employment alternatives and because of the way in which real costs are perceived. Simple firm budget information may be more useful in small-scale fisheries.

Economic data needs for small-scale fisheries can be easily delineated into production statistics and market statistics. Similarly, research needs of fisheries such as the lobster fishery can be delineated into production, consumption and demand, marketing, and social and economic profiles. Data collection in small-scale fisheries may by necessity have to be centered at the fisherman level due to the cost of data collection and sociological attributes of the fishermen.

Sophisticated economic controls such as limiting vessels or gear, using quotas and imposing taxes or fees on small-scale lobster fisheries are unlikely to be successful in the pure sense. Licensing vessels and gear would necessitate licensing the entire trap fishery since lobsters are often a by-catch. Introducing quotas without a buying and selling option would not guarantee long-run economic efficiency. However, a buying and selling option might lead to concentration in the fishery since many small-scale fishermen might be tempted to sell their quota for short-term capital gain. Introducing taxes and fees would necessitate a system through which economic rent could be extracted from the fishery. Aside from the problems of determining the amount of rent to be extracted, the social and political acceptance of this management tool in small-scale fisheries is questionable.

Effective management for economic goals requires the consideration of economic efficiency, biological effectiveness, income distribution and political feasibility. In most small-scale fisheries and in developing countries the management objectives may differ from those in an already developed fishery.

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