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Aquaculture Economics: An Overview

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Abstract: The economics of aquaculture is reviewed on two levels: micro and macro. Microeconomics in aquaculture deals mainly with the management measures and elements affecting the efficiency of operation at the farm level, while macro-economics addresses the assessment of social benefits and costs of an aquaculture project. If aquaculture is socially beneficial but unattractive to private investors, public support on credit, marketing, extension, training, and research may be appropriate, especially during the early stages of development.

The importance of economic analysis is emphasized since it provides a basis not only in the decision making of the individual farmer, but also in the formulation of aquaculture policies. Thus, greater attention should be focused on the improvement of economic data for analysis.

Introduction

In recent years, increasing attention has been given to aquaculture in many parts of the world and importantly in the tropics where, by and large, aquatic plants and animals grow faster than in the temperate zone. Aside from increasing awareness of problems in the marine fisheries sector such as the rising costs of fuel, water pollution, overfishing, and the extension of exclusive fishing zones, this can also be attributed to: (1) the need to produce more fish to meet the demand of the rapidly increasing population; (2) the development possibilities for aquaculture in view of the extensive inland, brackish and marine water areas available; (3) the suitability of aquaculture to small-scale family-managed operations; (4) the feasibility of integrating aquaculture with agriculture and small-scale fisheries; and (5) the improvements in fish culture technology. In the long run, the contribution of aquaculture to nutrition, income, employment, foreign exchange and social stability can be expected to increase substantially. However, proper management is necessary for aquaculture to realize its full potential.

Assessment of the economics of aquaculture, like agriculture, can be carried out from different points of view depending on the need and scope. It is appropriate to make such an assessment on two levels: micro- and macro-economics. Micro-economics analysis in aquaculture concerns a single farm or an enterprise and deals mainly with the management measures and elements affecting the efficiency of operation. Macro-economics addresses itself to broader areas. It concerns the economy as a whole. Macro-economic analysis serves as a basis in determining aquaculture policy of the country. This type of analysis is usually connected with the general role of fish culture viewed as a source of protein, employment, foreign exchange, and income distribution. It often involves the assessment of social net benefit of fish culture with alternative means of achieving the same purpose and the evaluation of institutional actions required during the development.

Micro-Economics

Major Costs of Production

Most aquaculture is presently undertaken in fresh and brackish water ponds or similar enclosures. In consequence, bio-technical and economic conditions predominate for this type of husbandry of aquatic organisms. Therefore, the costs of production in aquaculture usually vary with local environmental and economic conditions, farm size, species culture, type of culture system and skill of management. Generally speaking, feed and/or fertilizer, seed and labor are the major variable costs for aquaculture (Shang 1981a). Feed costs usually reflect the position of the species in the food chain and intensity of the culture system. Herbivorous are usually cheaper to produce than omnivorous, and should be cheaper than carnivorous species (see earlier chapters and also Shang 1981b). The more intensive the culture system involved, the higher the cost of feed/fertilizer is likely to be. Cost of feed per unit of output for a given species depends primarily on two elements: the conversion ratios of feed to flesh and the unit price of feed. The cost of feed can be reduced by an improvement in the conversion ratio and/or by lowering the unit price of feed. The conversion ratio can be reduced by eliminating waste and improving the feed formula. The unit price of feed may be lowered by utilizing locally available materials or by-products for feed ingredients instead of imported feed.

A reliable supply of good quality fish seed (fry in the case of fish, larvae for crustaceans and molluscs) at a reasonable price is one of the most important requirements for aquaculture development. For those species where artificial hatching has not been successful, the cost of seed usually accounts for a high percentage of the total variable cost (Shang 1981a). Expensive fry or larvae means high cost of production for the species, which is transferred to consumers by higher prices or to the producers in reduced profits. The ultimate solution to the shortage of feed appears to be breeding in captivity. There are definite economies of scale in hatchery operation for those species where artificial hatching has been successful. For instance, the price per thousand post larvae of marine shrimp range from US $ 12 for a hatchery of a scale to supply a 40-ha farm to US $ 34 for a hatchery of a scale to supply a 8-ha farm (Simon 1983).

Labor cost is another major expense of aquaculture because, in most cases, mechanization has not been sufficiently developed to reduce the intensive use of labor. This is more of a problem in the developed countries than in developing countries where labor is cheap and the prime requirement is employment and income generation. However, all of this will change as economic conditions change.

The labor requirement per unit of pond for small farms is usually higher than for large farms. For instance, the amount of labor required per unit of pond for a 4-ha freshwater prawn farm in Hawaii is estimated to be almost 3 times greater than that of a 40-ha farm (Shang 1981c). Additional labor is required for a more intensive type of operation because stocking, feeding, and harvesting are usually done more frequently. However, labor requirement and hence labor cost per unit of output may be relatively low compared to that of an extensive operation.

The initial construction costs are the most important fixed expenses of aquaculture. Generally, the larger the pond size (or facility), the greater is the efficiency of land and water utilization, and the lower are construction costs. The size, shape and depth of the pond and the clearing work required will affect the cost of construction. Economy of construction and efficiency of operation are usually the primary factors in site selection and construction.

Economics of Various Culture Systems

The total world production through aquaculture in 1980 was about 9 million t and accounted for approximately 12% of the total world supply of fish (Pillay 1981). In developing countries today, the majority of aquaculture operations are still on a subsistence level. Subsistence aquaculture is usually characterized as labor intensive, simple to operate, having low costs, and using low price and simple life cycle species (e.g. *tilapia*), possibly in combination with agricultural activities. A significant portion of the production is consumed by producers as a supplemental source of animal protein. By contrast, commercial fish farming is solely a profit motivated operation. Commercial fish farmers may choose to invest in relatively complex, capital-intensive schemes involving a relatively high cost, to produce high value species destined for domestic markets or for export trade (predominantly shrimp but also eels, groupers and other carnivores).

The selection of culture systems (extensive, semi-intensive, and intensive) of commerical aquaculture is usually determined by the supply and relative cost of labor, capital, water and land as well as culture technology. Extensive culture techniques (use of traditional practice with minimum inputs) are usually employed in places where there are an abundant supply of inexpensive labor, large areas of suitable land and water available at low cost, but where capital is relatively scarce. Such culture systems usually result in a low level of production per unit water area but the cost of production per unit of fish may also be low due to limited inputs. This kind of operation is especially appropriate if the objective of national development is to increase employment opportunities in rural areas and to produce cheap animal protein for local consumption.

In areas where land, water and labor are relatively expensive compared to capital, intensive culture systems using improved culture techniques with more inputs, are usually employed, if the culture technology is available. Under this system, stocking, feeding and water quality are to a large extent controlled. The principal aim of this system is to achieve economy of production by rearing more animals in less time and space and by using more inputs, but of course, only if the additional revenues offset additional costs.

Although the production per unit area may be higher as the intensity of the culture system increase, the cost of production per unit of output may not rise initially, but may eventually increase after a certain level of intensity.

For example, the cost of production per kg of shrimp in Ecuador for a 5-ha shrimp farm would initially decrease with the increase in farming intensity, and then increase (Shang 1983). The more intensive type of operation appears to increase the return to land while the less intensive type of operation increases the return to capital. This fact is supported by a cost study of marine shrimp culture in Taiwan (Shang 1983), and catfish farming in Thailand (Paneyotou et al. 1982).

A survey of shrimp farms in Ecuador also indicated that the yield per unit of pond area is much higher with fertilizer and feeding than without, and that stocking with large size post larvae, although more costly, reduces the rearing period and increases the possible number of crops per year. As stocking density increases, production per unit area improves, but the growth rate of the shrimp decreases (Shang 1983). Shrimp must be either harvested at a smaller size or the rearing period be extended. Smaller size shrimp command a relatively low price while a longer rearing period means higher production costs. The economic tradeoffs between high and low stocking density, feeding and no feeding, and stocking small and large post larvae should be evaluated in order to maximize profits.

An aquaculture system can also be classified into two categories by the number of species stocked: monoculture and polyculture. Monoculture is the husbanding of a single species in a growing area while polyculture involves rearing several compatible species to make more efficient use of the growing environment. Significant increases in the production of certain species are often obtained through polyculture (Bardach et al. 1972; Shang 1981a). However, when a high-value species is cultured as a primary crop, polyculture with a low-priced species may reduce the net income of the operation. A survey of shrimp farms in Taiwan indicates that the average gross revenue per ha of polyculture farms (shrimp and milkfish) is about half that of monoculture farms (Chen 1980). In general, it would be a mistake to reduce the stocking density of high-priced species in order to accommodate relatively low-priced species as a secondary crop unless it is for biological reasons such as the control of unwanted species and excessive reproduction. In purely monetary terms, farming a high-priced species as a primary crop in polyculture is advisable only if the total net income from a given water area is thereby increased.

Conversely, when a high-priced species is polycultured as a secondary crop with a less valuable species as the primary crop, the net income from a given water area may be greater compared to monoculture of relatively low-priced species. For example, in the Philippines and Indonesia, the net income from polyculture of milkfish (primary species) and shrimp increases twofold compared to the monoculture of milkfish (Shang 1976).

Integrated aquaculture with livestock in many cases increases production of animal protein from the same unit area, reduces the cost of production, especially the cost of feed and/or fertilizer, and increases the profit of the entire operation (Shang and Costa-Pierce 1983).

Most published references on the economic aspects of aquaculture only provide a rudimentary budget analysis. It is difficult to make optimal use of available resources based on such studies. Successful aquaculture operations depend on biological, physical and economic elements during a dynamic production process. Profitable operations can only be achieved through better understanding of these relevant elements as well as their interrelationships in the entire process. This is not an easy task for any producer to perform without the assistance of a proper tool. A systems approach which can integrate all these important elements and help the producer to locate the optimal course of action will contribute immensely to the success of the operation. To develop such an approach requires collaborative efforts of biologists and economists.

Macro-Economics

Benefit-Cost Evaluation

The reviews thus far dealt mostly with micro-economic analysis at the farm or firm level. An appraisal of a public investment project based exclusively on business criteria may not be satisfactory. It should also be analyzed from society's point of view. Social benefits and costs have a broader scope than revenues and costs of the private sector because the former includes both direct (primary) and indirect (secondary) effects on society as a whole. Except having direct effects, a project may create benefits and costs either for other segments of the sector or other sectors of the economy. These effects are sometimes referred to as "externalities or spillovers". External effects of a project will need to be taken into consideration when they alter the physical production possibilities of other producers. For instance, increases in production of aquaculture may improve nutrition for the rural poor, create employment, or earn foreign exchange, but aquaculture development is often in conflict with land and water use of other economic activities such as agriculture, fisheries, recreation, urban development, etc. When such conflicts occur, social benefits and costs of a given project should be evaluated.

The imperfection of the market usually introduces a divergence between the actual and true value of the product and the actual and true cost of inputs. In the evaluation of social benefits and costs, "shadow price" (true value of product or true cost of input) is usually used. For instance, when the price of a species is supported by the government to encourage local production, the level of current prices would not reflect the economic value of the product because it involves income transfer to local farmers. A shadow price that is lower than the existing price should be used in this case. Also, it is often mentioned that the opportunity cost of unskilled labor in regions of high unemployment may be nil. This statement might not be true because of the seasonal need for labor that characterizes agriculture, fishing and aquaculture. In addition, to make unskilled labor employable, training and relocation costs may be involved. In this case, adjustments must be made to reflect the true cost to society.

It is sometimes suggested that a "multiplier effect" should be included in estimating the secondary benefits of a large-scale investment project and one notes that it is possible to estimate the "value added" by aquaculture in an economy from the benefit and cost data. Value added is the payment to individuals for labor, management, the use of personal property and capital, and risk taking. Such payments are in the forms of wages, rent, interest, depreciation, and profit. The sum of these payments is very useful for assessing the impact of aquaculture on the local economy by evaluating such income and employment multipliers as may be involved.

Many projects have intangible benefits and costs that cannot be quantified. Their evaluation is a matter of judgment in the final decision-making process. However, it is important to take these intangible effects into consideration.

Management and Development Strategies

The available data indicate an increase of over 42% in world production through aquaculture in a five-year period (1975–80). The projected doubling of production in the ten-year period, to 1985, may be attainable provided there are an accelerated transfer of technologies, massive financial investments, suitable legislation, intensive research, manpower training and development of institutions and other essential infrastructures (Pillay 1981).

Aquaculture management from society's point of view encompasses two major strategies: maximizing economic efficiency and social benefits. As to the former, economic theory emphasizes efficiency as the greatest margin of revenues over costs. However, the relentless pursuit of economic efficiency without the consideration of income distribution may result in socially inferior positions for some members of society since the market mechanism usually allocates very little to the poor. For instance, if resources were to be allocated to achieve the highest monetary returns this would tend to lead, on economic efficiency grounds, to the favor of large-scale operations and high-value species while small-scale operations and staple species would be neglected and inequality within the industry would result. In view of the importance of small-scale subsistence fish farms in many developing countries, it seems justified to support this subsector certainly for now, not so much for economic return but for social benefits which may not be easily measured in monetary terms.

If aquaculture is socially profitable but unattractive to private investors, promotion of it through subsidies may be appropriate, especially during the earlier stages of development. Subsidies on credit, marketing, costs of certain types of inputs, and even on consumer prices of fish can reduce the costs of production and increase revenue, if the demand for fish is price elastic. Many of the existing commercial and institutional credit programs benefit only well-to-do farmers. Since the majority of the fish farmers in the developing countries are small-scale operators, meeting the needs of the small-scale farmers should be emphasized in institutional lending. Public supports in providing market-related facilities and services such as preservation, storage, processing and transportation are also necessary for small-scale farms. In substituting institutional for traditional credit and marketing services, care must be given to existing social and economic relationships between fish farmers and middlemen. In many cases, the motivation for land owners and middlemen to lend is not merely to secure a high rate of interest but also to secure regular supplies of fish and to ensure a continued business relationship (Lawson 1979). Since most borrowing is undertaken within the traditional sector itself and is based on mutual trust and respect, to replace this system with institutional lending and marketing may be costly and difficult, perhaps even ineffective.

Aquaculture has a long history in many countries, but present culture technology has been developed largely by trial and error rather than by scientific research. The productivity of existing resources can be increased significantly through applied genetics and technological improvements. One of the major constraints in technological improvement is the lack of trained and experienced practical aquaculturists in most tropical nations. Therefore, the establishment of effective training, research and extension programs by public support are of special significance.

The potential of aquaculture for development in an economy is determined by factors that are both internal and external to the sector and to the economy. There are five major areas which influence aquaculture development in a specific location: (1) the relative economics of rearing and marketing various species; (2) the comparative advantages of rearing and marketing aquaculture species which compete with those raised in other regions in either domestic or foreign markets; (3) the relative economics of aquaculture versus other economic activities, for instance animal husbandry, that either require the same inputs or compete in the same product markets; (4) the expansion of other economic activities that produce positive or negative externalities for aquaculture; and (5) the existing regulations and institutions related to aquaculture development.

As previously mentioned, commercial aquaculture is motivated by profit making. The selection of species for culture is usually determined by the relative economics of production and market demand, if culture technology is not a limiting factor. A high-value species may be chosen over a low-value species if the profitability is higher; many milkfish farms being converted to marine shrimp production in Southeast Asian countries (Smith 1981) is evidence for this. Species having high elasticities of demand (both price and income) usually have potential for development.

The comparative advantages of two or more regions (or countries) in producing a species are usually measured by the relative differences in production and in cost of producing and marketing the species. The country with lower production and marketing costs per unit of quality product will have a distinct advantage in a competing market and will ensure an expanding industry (e.g. shrimp production in Ecuador competes through cheap labor and land, ample suitable water, etc.).

Aquaculture products may compete with catches of capture fisheries and other animal meats in the market. The expansion potential of capture fisheries is particularly important to the development of aquaculture. Where (and when) further increases in production from capture fisheries are limited, increasing demand may encourage an expansion of aquaculture (e.g. shrimp culture in the Kerala Coast in India). As for inputs, aquaculture often competes with other economic activities for limited resources such as land, water, capital, labor, feed and/or fertilizer and the like. The extent to which aquaculture will successfully compete for limited resources depends mainly on the relative efficiency of production which, in turn, can be increased by reducing its costs through improved practices and technology and thereby increasing the revenue of operation. The more the relative efficiency of aquaculture improves, the more justified it becomes to use the limited resources for expansion.

The activities of other sectors may indirectly enhance or constrain aquaculture development. For instance, the development of marketing infrastructures for capture fisheries may benefit the distribution of aquaculture products. On the other hand, the development of coastal areas for industrial, urban or agricultural uses may create water pollution, and severely inhibit aquaculture.

Many legal constraints restricting the development of aquaculture exist in certain countries, such as curbs on importation of certain species and on placing structures in the open waters, difficulties in obtaining permits for production and marketing, and lack of land ownership or property rights. The lack of adequate institutional supports for research, credit, marketing, and extension may be further bottlenecks of aquaculture development.

Strategies for aquaculture development should, of course, conform to the objectives of national development. The production of staple species (e.g. carp, tilapia, mullet, milkfish, etc.) may be encouraged if the major national objective is to improve the protein diet of low-income groups and if there is demand for these species. The production of high-priced species (e.g. prawn, shrimp, eels, etc.) may be emphasized if earning foreign exchange is the principal objective. Production of both staple and high-price species may be appropriate if an increase in rural employment is the major development policy (Shang 1981a). It should be stressed that all of these development strategies must be evaluated by comparing their cost-effectiveness with ways of achieving the same objective by other means than aquaculture.

Vertical integration of various measures is important here, such as: resource assessment; laws and regulations to ensure property or use right; regulations to prohibit pollution; training and extension services to improve production; preserving and processing facilities to improve quality and added value; market reforms to raise farm prices and lower retail prices; and credit schemes to finance technical and institutional improvements. All of these measures have to be pursued in an integrated fashion for an efficient development program. Appropriate development policy cannot be formulated without first knowing the potential of the resources. In addition, without property or use right, prospective farmers would have little incentive to invest, the coastal and inland waters may be polluted without controls, and adoption of new culture technology without adequate training of the fish farmers can result in failure. Advancement in culture technology without improvement in processing and marketing infrastructures can glut the local market and reduce farm prices while improvement in marketing infrastructures without correcting market exploration can result in low prices for fish farmers and high prices for consumers. All of the improvements cannot be accomplished without an adequate credit scheme and without research.

Conclusion

Research on the economics of aquaculture plays an important role in the development of aquaculture. It provides a basis, not only for decision making among farmers, but also for formulating public aquaculture policies. Reliable economic data in aquaculture lag far behind the wealth of information available on the technology. Greater attention should be focused on the improvement of economic data so that more critical economic appraisal can be conducted and efficient management decisions can be made by both commercial entrepreneurs and by development planners for the public sector.

References

Bardach, J. E.; Ryther, J. A.; McLarney, W. O.: Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley-Interscience, New York 1972.

Chen, C. C.: Economic Analysis of *P. Monodon* Culture in Taiwan. Agricultural Development Council. Taipei, Taiwan 1980 (In Chinese).

Lawson, R. M.: New Directions in Developing Small-Scale Fisheries. The Agricultural Development Council, Inc., New York 1979.

Panayotou, T.; Wattanutchariya, S.; Isvilanonda, S.; Tokrisna, R.: The Economics of Catfish Farming in Central Thailand. Kasetsart University Research and Development Institute and International Center for Living Aquatic Resources Management. 1982.

Pillay, T. V. R.: State of Aquaculture, 1981. Presented at the World Conference on Aquaculture, held in Venice, Italy 1981.

Shang, Y. C.: Economics of Various Management Techniques for Pond Culture of Finfish. South China Sea Fisheries Development and Coordination Programme. Manila, Philippines 1976.

Shang, Y. C.: Aquaculture Economics: Basic Concepts and Methods of Analysis. Westview Press. Boulder, Colorado 1981a.

Shang, Y. C.: A Comparison of Rearing Costs and Returns of Selected Herbivorous, Omnivorous, and Carnivorous Aquatic Species. Marine Fisheries Review 43, 9 (1981b)

Shang, Y. C.: Freshwater Prawn Production in Hawaii: Practices and Economics. Aquaculture Development Program, State of Hawaii and University of Hawaii Sea Grant College Program. Honolulu, Hawaii 1981c.

Shang, Y. C.: The Economics of Marine Shrimp Farming: A Survey. Presented at the First International Biennial Conference on Warm Water Aquaculture – Crustacea, Brigham Young University – Hawaii Campus, Laie, Hawaii 1983.

Shang, Y. C.; Costa-Pierce, B. A.: Integrated Aquaculture – Agriculture Farming System: Some Economic Aspects. Presented at the World Mariculture Society Meeting held at Washington, DC 1983.

Simon, C. M.: Large Scale Commercial Application of Penaeid Shrimp Maturation Technology. Proceedings of World Mariculture Society, 13, 1983.

Smith, I. R.: A Research Framework for Traditional Fisheries. International Center for Living Aquatic Resources Management. Manila, Philippines 1979.