Fish Nutrition Research in Asia

Proceedings of the
Third Asian Fish Nutrition Network Meeting

Edited by

S.S. De Silva

1989

**Published by the Asian Fisheries Society
in association with the
International Development Research Centre of Canada**

Contents

Economic Parameters in Nutritional Studies

DANNY ATTAPATTU
Department of Economics
University of Ruhuna
Matara, Sri Lanka

CHRISTOPHER MacCORMAC
International Development Research Centre
P.O. Box 101
Singapore 9124

Attapattu, D. and C. MacCormac. 1989. Economic parameters in nutritional studies, p. 90-100. *In* S.S. De Silva (ed.) Fish Nutrition Research in Asia. Proceedings of the Third Asian Fish Nutrition Network Meeting. Asian Fish. Soc. Spec. Publ. 4, 166 p. Asian Fisheries Society, Manila, Philippines.

Economic analysis of aspects on nutrition can play an important role in determining the commercial viability of aquaculture production systems. Changes in feed formulation and methods of feeding must be subjected to an economic analysis before they are recommended for use by aquaculture producers. Economic analysis techniques are readily available for this purpose. This paper focuses mainly on the application of economic analysis to the following issues: (a) estimation of input-output relationships and determination of economically optimal level of feed use (b) determination of least cost combination of different feeds (c) determination of output mix and, (d) derivation of minimum cost feed formulation.

Finfish culture is an animal husbandry process. It has many similarities to other types of land based animal husbandry, one of them being that prepared feeds is an important, if not the most important input in the production process. The objectives of providing prepared feeds in aquaculture are similar to land based animal production, i.e., maximize growth rates, increase production per unit area per unit time, increase reproductive efficiency, increase resistance to disease, and minimize mortality (Cole and Ronning 1986). The cost of feeds in aquaculture can often exceed 50 percent of total production costs, rising to as high as 75 percent (Shang 1981). This is comparable to hog, beef cow, feeder cattle and caged layer livestock enterprises (Herbst 1968).

The preparation of feeds requires scarce resources, i.e., feed ingredients, labour, capital. All of these resources have alternative uses and 'values' associated with those uses. If they are not allocated to preparing fish feeds, they could be used for other livestock feeds, other farming and/or industrial activities. Economics is the science of the allocation of scarce resources among competing uses. With reference to animal feeds and feeding methods economic analysis is an accepted and integral part of commercial livestock operations and experimental research in both developed and developing countries (Fine and Lattimore 1982).

While the authors cannot claim to have conducted an extensive review of the finfish nutrition literature in Asia, it seems fairly safe that economic analysis of commercial and experimental finfish feeding practices in Asia is very limited. There are, of course, exceptions (see Pullin and Shehadeh 1980; Hopkins and Cruz 1982). There are probably three main reasons for this. First, a historical lack of trained and experienced aquaculture economists in Asia; second and perhaps more important is that the state of knowledge of tropical Asian finfish nutrition itself, for both laboratory and producer level environmental conditions, is significantly less as compared to temperate species and producer culture environments. This means that the specific (species, culture system) objectives of feeding are not as well defined, nor are the technical relationships and their efficiencies between feed and species performance. While recognizing that the known nutritional requirements for all commercial temperate species is far from complete, it appears to be even less so for the tropical species (Cho et al. 1985). This means that economic analysis of feeds and feedings, as an aquaculture enterprise management practice provides more accurate estimates of probability of economic feasibility in proportion to the certainty of the feed input/species performance relationship. Third, tropical Asian finfish aquaculture is not relatively 'industrialized' as for example, the non-ruminant livestock sectors. This relates to feeds in the sense that the quality of feed used by producers in aquaculture is highly variable due to local formulation, non-standard processing (ingredient content, balance of ingredients, storage, etc.), varying local availability on ingredients for use as feeds and a wide range of mostly manual feeding methods (Cho et al. 1985). A high degree of variability in feed quality both within and between aquaculture enterprises growing similar species makes it extremely difficult for the economist or aquaculture producer to formulate least-cost feed formulations or diets, with broad application. Unless there is a minimum level of certainty as to the feed (or ingredient) quality, it is not possible to calculate a least cost ration. Such a calculation (as will be shown later) depends on an estimate of the marginal rate of technical substitution of alternative (feed) inputs to maintain a given level of species performance. The authors are not arguing for highly industrialized finfish production in Asia, but stressing the need for the development of feeds of relatively known quality when used by producers, otherwise the economic feasibility of the use of those feeds is very difficult to calculate.

In addition to the economic analysis of specific technical objectives for providing feeds (as stated above), there is an additional economic analysis of finfish that is important. That is the comparison of the economics of supplementary feeding to achieve species/system performance as compared to alternative, i.e., capital intensive technologies. In Asia, where access to large water areas and/or borrowed capital to develop extensive and/or capital intensive (controlled environment) systems is often not feasible, supplementary feeding is probably the principal means of intensifying production per unit area per unit time. This is especially true for small scale rural producers. Also, supplementary feeding provides producer with a high degree of flexibility and control in varying his or her production and total production costs. This allows the producer to react more economically to changes in local demand (quantities and price) for fish.

It appears from this discussion that economic analysis of nutrition can play a very important role in determining the commercial viability of aquaculture production systems. The major objective of this paper is to examine the application of economic theory and techniques to the decision making problems faced by fish farmers with respect to the use of supplementary feeds as a major input in their production systems. Basically these decisions are concerned with the following issues related to finfish nutrition:

a. Estimation of input-output relationships and determination of economically optimal level of feed use

b. Determination of least cost combination of different feeds

c. Combination of fish species output using a single type of feed, and

d. Derivation of minimum cost feed formulations.

The areas of microeconomics dealing with the theory of production and costs are obviously useful in making decisions on these issues. The applications of economic theory to analyse each of the above issues are presented in this paper.

Estimation of Input-Output Relationships and Determination of Economically Optimal Level of Feed

One of the most important practices in aquaculture is the use of supplementary feed to improve the productivity and nutritional level of fish. Decisions on inputs and outputs cannot of course, be taken independently as there are technological relationships between inputs and outputs which restrict the options available to management. This technological relationship between input and output is commonly referred to as the production function. Production function specifies the maximum possible output that can be produced for a given amount of inputs or, alternatively, the minimum quantity of inputs necessary to produce a given level of output. Production functions are determined by the technology available to the firm. Any improvement in technology results in a new production function.

The basic properties of production functions can be illustrated by examining a simple unconstrained single-output, single-input production process. Consider a simple aquaculture production system where the output of fish (Q) is dependent upon the quantity of supplementary feed (X) used. All other inputs and technical knowledge are assumed to be fixed during the period of production. The production function for this system can be expressed as the following unspecified relationship:

$$Q = f(X)$$

Where Q is quantity of fish produced and X is quantity of supplementary feed consumed. Table 1 illustrates a hypothetical production function for this single-input, single-output production system. This Table shows the maximum quantity of fish (Q) that can be produced with a specific quantity of supplementary feed (X) while other factors remain constant.

Table 1. Hypothetical production function for a single input, output system.

Units of Feed (Bags)	Units of Fish (kg)	Marginal Product (MP) (kg)	Average Product (AP) (kg)	Price of Fish ($/kg)	Marginal Revenue Product (MRP) $	Marginal Factor Cost (MFC) $/Bag	Total Revenue $	Total Cost $	Profit $
1	9	9	9	2.00	18.00	38.00	18.00	38.00	- 20
2	32	23	16	2.00	46.00	38.00	64.00	76.00	- 12
3	63	31	21	2.00	62.00	38.00	126.00	114.00	12
4	96	33	24	2.00	66.00	38.00	192.00	152.00	40
5	125	31	25	2.00	62.00	38.00	250.00	190.00	60
6	144	19	24	2.00	38.00	38.00	288.00	228.00	60
7	147	3	21	2.00	6.00	38.00	294.00	266.00	28

This production function can be expressed mathematically as: $Q = 10X^2 - X^3$.

The input-output relationship given in Table 1 can also be displayed graphically as shown in Fig. 1 assuming that the underlying production function is continuous in nature. Fig. 1 shows that as more of supplementary feed is employed while all other inputs being held constant output of fish will first tend to rise but eventually, at least, a point will be reached where additional quantity of feed will yield diminishing marginal contribution to total output.

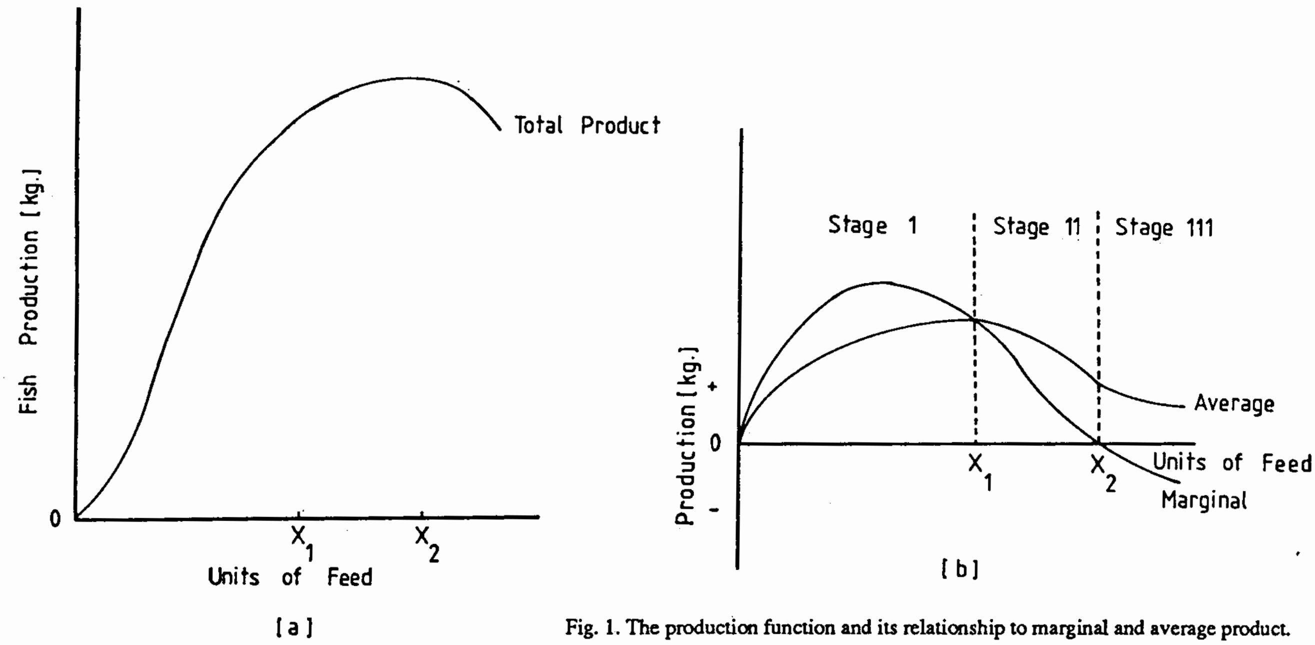

Fig. 1. The production function and its relationship to marginal and average product.

This relation is known in production theory as the "Law of Diminishing Returns". The marginal product of an input X (MPx) is defined as the change in output (Q) resulting from a very small change of this input keeping all other things constant. For a discrete total product function, the marginal product is estimated by the relationship:

$$MPx = \frac{\Delta Q}{\Delta X}$$

For a continuous total product function the marginal product can be derived by taking the partial derivative of the production function with respect to the input. Thus the marginal product of input X is given by:

$$MPx = \frac{\Delta Q}{\Delta X}$$

Graphically the marginal product is equal to the slope of the total product curve. In our hypothetical production function presented in Table 1, marginal product of feed continues to increase until four bags of supplementary feed have been added but starts to decline when the fifth bag is added. Therefore, with the fifth bag we encounter diminishing returns, eventhough the total fish output continues to increase until the seventh bag of feed is used.

Another important concept which is frequently used in input-output relationship is the average product (AP) and defined as the total output (Q) divided by the number of units of variable input (X) used:

$$APx = \frac{Q}{X}$$

The average and marginal product curves that correspond to the total product curve in Fig. 1 (a) are shown in Fig. 1 (b). We can see from Fig. 1 (b) that there are three ranges of input utilization which can be used to identify the rational and irrational stages of production. Stage I is characterized by an excessive amount of fixed input relative to the quantity of variable input employed. Average product of the variable input in this stage is increasing, compelling the producer to increase the use of variable input within this stage which extends from the origin to X_1. The input utilization in Stage I does not lead to cost minimization for any level of production.

The operation in Stage III is also irrational as the marginal product of the variable input is negative in that range. Stage II lies between X_1 and X_2 is characterized by diminishing returns to the variable input over its entire range which is known as the area of rational economic production. Therefore, if production is to take place it will occur somewhere in Stage II.

In order to realize maximum profits a firm must find out the rates at which to apply the inputs. The production function relationships discussed so far are insufficient to determine the optimal (profit maximizing) input use in a production system. It is necessary to combine this technological information with economic data such as the prices of inputs and outputs prevailing in the factor and product markets in order to determine the economically efficient input level the producer should use. To achieve this, the firm must balance the returns from employing supplementary feed against the cost of feed.

The addition to a firm's total revenue when one more unit of variable input (feed) is employed is called the marginal revenue product (MRP) of that input. It is equal to the marginal product of the variable input multiplied by the firm's marginal revenue (if the firm is a price taker in the product market, firm's marginal revenue will be identical to the market price of the product). The corresponding addition to the firm's total cost resulting from applying additional unit of variable input (feed), all other inputs unchanged, is called the marginal factor cost (MFC). A firm is in profit maximizing position with respect to input utilization, if the marginal revenue product of the variable input is equal to its marginal factor cost (Asimakopulos 1978). This equilibrium condition can be written as:

$$MRP_x = MFC_x$$

So long as marginal revenue product exceeds marginal factor cost, profits must increase and the firm will increase the employment of inputs if it aims at profit maximization. Similarly, when the marginal revenue product is less than the cost of the factor, marginal profit is negative, so the firm would decline to employ additional units of that factor. As shown in Table 1, profits are maximized with the use of six units of feed when MRP equals MFC.

Least-Cost Combination of Different Feed Inputs

The presence of more than one complementary/substitutable feed inputs in aquaculture production systems makes the analysis of optimal combination of feed inputs more intricate.

When there are only two feed inputs in the production function, the choice of optimal combination of two inputs can be analysed graphically using isoquants and isocost curves. An isoquant is a line joining all points representing combinations of two variable inputs which when combined efficiently, produce a specified level of output. In Fig. 2 a production function with two variable inputs is depicted in the form of a set of isoquants. The isoquant labeled Q_1 shows the various combinations of rates of inputs X and Y that produce 300 kg of fish.

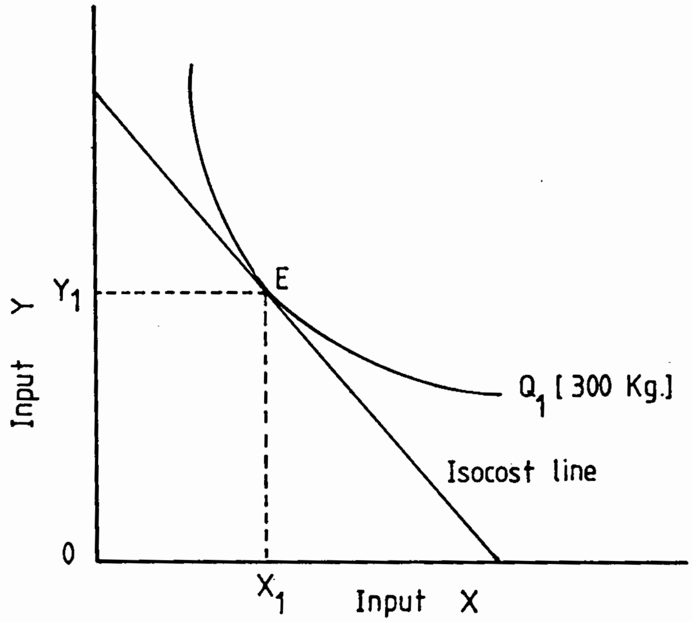

Fig. 2. Optimal input combination.

The numerical value of the slope of an isoquant provides the key to the substitutability of the two inputs. The slope of the isoquant shown in Fig. 2 is simply the change in input Y (ΔY) divided by the change in input X (ΔX). This relationship known as the marginal rate of technical substitution ($MRTS_{xy}$) of the two variable inputs provides a measure of the amount of one input factor that must be substituted for one unit of the other factor if output is to remain unchanged. Thus:

$$MRTS_{xy} = \frac{\Delta Y}{\Delta X} = \frac{dY}{dX} = \text{Slope of the isoquant.}$$

It can be deducted that the MRTS is equal to the ratio of the marginal products of the two inputs as follows:

$$MRTSxy = \frac{\Delta Y}{\Delta X} = \frac{MP_x}{MP_y}$$

The production function shown in the form of a set of isoquants alone cannot determine the optimal combination of the two inputs producing a specified level of output. Data on input prices are required to determine the optimal input combination. Graphically, input prices can be introduced into the production function by adding an isocost line to the diagram of production isoquants. Isocost line is the focus of all combinations of factors the firm can purchase for the same expenditure. The slope of the isocost line is equal to the relative prices of the inputs, X and Y. Thus:

$$\text{Slope of isocost line} = \frac{P_x}{P_y}$$

Combining the production isoquants with the isocost line, it is possible to determine the optimal input combination required to produce a specified level of output. In Fig. 2, the optimal input combination occurs at point E where the isocost line and the isoquant are tangent. The optimal combination of factors required to produce the level of output Q_1 is X_1 and Y_1. At the point of tangency (E), the slope of the isocost line (relative input price: P_x/P_y) is equal to the slope of the isoquant (ratio of marginal products: MP_x/MP_y). Therefore, for optimal input combination, the ratio of prices of inputs must be equal to the ratio of their marginal products (Pappes and Brigham 1979). That is:

$$\frac{P_x}{P_y} = \frac{MP_x}{MP_y}$$

Or, alternatively, the ratio of marginal product to price must be equal for each input:

$$\frac{MP_x}{P_x} = \frac{MP_y}{P_y}$$

The economic principle for least-cost combination of inputs as shown above states that the firm employs various inputs in such a way that as the last dollar spent on each input contributes the same amount to output as a dollar spent on any other input. For example, with P_x = \$2 and P_y = \$4, a solution could be 6/\$2 = 12/\$4 or 2/\$2 = 4/\$4, which means the last dollar spent on each input will bring forth the same amount of output.

When the number of variable inputs in the production system is greater than two, it is not possible to use the graphical method to determine the optimality though the requirements for production at least cost would still be the same. This optimality condition can be expressed when the number of variable inputs is *n*, as:

$$\frac{MP_x}{P_x} = \frac{MP_y}{P_y} = \ldots\ldots = \frac{MP_n}{P_n}$$

When there are a number of inputs in the production system, the marginal productivity of different inputs are to be derived from an empirically estimated production function through differential calculus. Estimation of production functions involves the application of statistical techniques to cross-section or time series data (Heathfield 1971).

Combination of Fish Species Output Using a Single Type of Feed

A fish farmer may have been engaged in raising two types of fish species (A and B) using a single type of feed input. The farmer can produce more of either A or B product by reallocating its feed inputs between the two outputs. Graphically, this can be represented by a production possibility frontier (PP') as shown in Fig. 3. A production possibility curve shows all possible combinations of two products (A and B) that can be produced with all inputs available to the firm. When there is a resource constraint on the producer engaged in producing two products, he must find the optimal product mix which brings maximum profits.

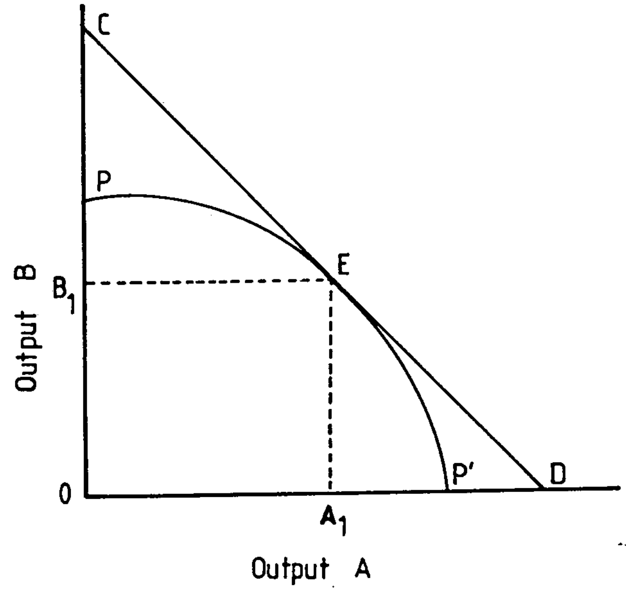

Fig. 3. Determination of optimal product mix.

The slope of the production possibility curve reflects the marginal rate of product substitution (MRPS) which indicates the amount one product (B) changes in quantity when the other product (A) is increased by successive equal units, when total resources used remain constant. MRPS is equal to the ratio of marginal products of the resource used. Thus:

$$MRPS_{A \text{ or } B} = \frac{\Delta B}{\Delta A} = \frac{MP_B}{MP_A}$$

To determine the optimal product mix, we need an additional tool, the isorevenue line which represents all possible combinations of two products (A and B) that, if sold, will give a fixed amount of revenue to the firm. This is drawn as C-D in Fig. 3. The slope of the isorevenue line is determined by the price ratios of the two products P_A and P_B. The isorevenue line may be derived from the equation:

$$R = P_A(A) + P_Y(B)$$

where R is total revenue; P_A and P_B are prices of A and B respectively and A and B are quantities of two products.

Graphically the optimal condition is defined by the point of tangency of the production possibility curve (P-P') and the isorevenue line (C-D). This point of tangency (E) fulfills the profit maximization criterion and leads to the most profitable combination of two products, A_1 and B_1. At the optimal point, the slopes of production possibility curve and the isorevenue line are equal:

$$\frac{MP_B}{MP_A} = \frac{P_A}{P_B}$$

This equilibrium condition known as the principle of equimarginal returns states that the last unit of expenditure (or cost of feed) on producing one product generates the same revenue as it would if applied to any other product, that is:

$$MP_A \cdot P_A = MP_B \cdot P_B.$$

(Allen et al. 1984).

Minimum Cost Feed Formulations: Linear Programming Approach

Linear programming is a class of mathematical programming models concerned with the efficient allocation of limited resources to known activities with the objective of meeting desired goals such as maximizing profit or minimizing cost. The distinct characteristic of linear programming models is that the functions representing the objective and the constraints are linear. Linear progfamming technique can be applied to the problems dealing with the determination of optimal feed mix for meeting the desired nutritional objectives at the least cost for the aquatic organisms. The application of this technique for optimization problems can best be explained by means of a simple illustration.

Assume for the sake of simplicity, that there are two types of feed stuffs or ingredients from which the supplementary feed is formulated. The nutritional elements to be considered for this formulation are protein and fat. The nutritive content and price of each ingredient are known. The constraint of the model is the minimum daily nutrient requirements for fish. Suppose the daily requirement of supplementary feed mix is 100 kg, now the problem is to determine the combination of two feed ingredients which will satisfy the daily nutrient requirements and entail the least-cost. The above information is summarized in Table 2.

The problem can be stated mathematically as follows:

$$\text{Minimize } C = 0.6X_1 + 0.8X_2$$

Table 2. Hypothetical example of cost and nutritive content of two feed ingredients.

Ingredient	Units per kg of ingredient Protein	Fat	Cost ($) per kg
X_1	0.10	0.40	0.60
X_2	0.50	0.08	0.80
Minimum daily requirement	22%	8%	

Subject to

$$0.40X_1 + 0.08X_2 \geq 0.08 \times 100$$
$$0.10X_1 + 0.50X_2 \geq 0.22 \times 100$$
$$X_1 + X_2 = 100$$

and

$$X_1, X_2 \geq 0$$

The first equation represents the cost function based on price information of feed ingredients and constitutes the objective function of the linear programme. The inequalities that follow are the constraints necessitated by daily requirements of nutrients. Let X_1 and X_2 be the amounts of feed ingredients used in producing 100 kg of feed mix. The last inequality refers to the non-negativity restriction. The above mathematical representation of least cost feed formulation problem can be easily solved with the help of a computer programme which is readily available at present.

Use of Micro Computers

Micro Computers and related software are valuable tools for conducting economic analysis of feed formulation and supplementary feeding trials. They are used for similar research in the livestock and food processing industries (Castle and Becker 1972). They have also been used in aquaculture (Allen et al. 1984). Hand held programmable calculators are often sufficient for analysing results of aquacultural feeding trials where quantity and type of feed are varied (and perhaps one or two other variables i.e. stocking density and species). The micro computer is an efficient way of analysing large quantities of survey data which attempts to identify the contribution of feed and feeding technology to output, using production function analysis (IDRC 1982; Hopkins and Cruz 1982). The authors recommend that fish nutritionists in the economics of supplementary feeding first attempt to involve a national fisheries economist in their work. If that is not possible, then contact a scientific research group known to be involved in livestock nutrition. It is quite likely that they will have an associate agricultural economist involved in related economic analysis or will be using software prepared and/or recommended by the economist for the analysis. Such software could be modified to fish nutrition/feeding research. The exception could be multi-species polyculture aquaculture systems with complex feeding relationship, due to the inclusion of species that feed at different 'levels' of the food chain. Special software would have to be written for these.

Conclusions and Recommendations

Economic analysis of new feeds, changes in feed formulations and methods of feeding are essential before they are recommended for use by aquaculturists. Given the significant cash costs of feeds relative to a producer's total cost, and that often these feeds have potential value in food production (i.e., fertilizer) or as human food their use must be as economic as possible in order to maximize both private and social benefits (i.e., improved nutrition) from increase in finfish production. It is recognized that adequate feeding is essential in order to have sufficient output and revenue to provide returns to other non-feed input use (i.e., fixed costs for pen, cage or pond construction). Supplementary feeding may also be economically justified if it can be demonstrated to be the most economic means of increasing production, compared to alternative extensive and/or capital intensive means. These latter methods often have associated 'social costs', i.e., environmental, abuse of traditional land/water use rights, income distribution; which can be partially avoided by intensifying economic production from "small scale" rural producers.

Economic analysis techniques are readily available for application to finfish nutrition research. Agricultural economists involved in livestock nutrition or preferably fisheries economists, should be associated with the definition and results analysis (and interpretation of the results) of experiments that evaluate new feed technology. Micro Computer technology is now within the means of most research institutions, and can be used for the economic analysis.

Given the above, there is no reason why the next few years should not see a significant increase in publication of finfish nutrition research results that includes the economic assessment of the new feed technology. Published nutrition research that excludes an economic assessment will be of less direct interest to individual producers, the aquaculture industry, or government, all of whom are potential investors in the new nutrition technology.

References

Allen, P., W. Botsford, A.M. Louis, A. Schuur and W.E. Johnston. 1984. Bioeconomics of aquaculture. Elsevier Science Publishers, Amsterdam, 351 p.

Asimakopulos, A. 1978. Microeconomics. Oxford University Press, Toronto, 450 p.

Brown, E.E. 1983. World fish farming: cultivation and economics. AVI Publishing Company Inc., Westport, 516 p.

Castle, E.N. and H.M. Becker. 1972. Farm business management. Macmillan, New York, 320 p.

Cho, C.Y., C.B. Cowey and T. Watanabe. (eds.). 1985. Finfish nutrition in Asia: methodological approaches to research and development. IDRC (Canada), 154 p.

Cole, H.H. and M. Ronning. (eds.). 1986. Animal agriculture. W.H. Freeman and Company, San Francisco.

Fine, J.C. and R.G. Lattimore. (eds.). 1982. Livestock in Asia: issues and policies. IDRC (Canada).

Heathfield, D.F. 1971. Production functions. Macmillan, London, 91 p.

Herbst, J.H. 1968. Farm management. Stipes Publishing Company, Illinois.

Hopkins, K.D. and E.M. Cruz. 1982. Integrated animal-fish farming project: final report. ICLARM Technical Reports 5. International Center for Living Aquatic Resources Management, Philippines. 96 p.

IDRC. 1982. Aquaculture economic research in Asia: Proceedings of a Workshop Held in Singapore 2-5 June, 1981, 128 p.

Kifle, W.B., G.R. Potts and R.M. Drysdale. (eds.). 1983. By-product utilization for animal production. IDRC (Canada), 158 p.

Pappes, J.L. and E.F. Brigham. 1979. Managerial Economics. Dryden Press, Illinois, 656 p.

Pullin, R.S.V. and Z.H. Shehadeh (eds.) 1980. Integrated agriculture-aquaculture farming systems: ICLARM Conference Proceedings No. 4. International Center for Living Aquatic Resources Management, Philippines. 258 p.

Shang, Y.C. 1981. Agriculture economics. Westview Press, Colorado.