CHAPTER 8

Economics of Feeding

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Introduction

The number of aquaculture farmers who adopt higher stocking densities and provide supplementary feeds to fish stocks is increasing because of increased production and improved profits. For example, in shrimp culture, the natural productivity of the water may generate from 100 to 300 kg/ha/yr and fertilization may further increase production to 600-1,000 kg/ha/yr in the Philippines. The use of feeds can raise production up to 20,000 kg/ha/yr in Taiwan and 30,000 kg/ha/yr in Japan.

In shrimp farming in the Philippines, although there is an increase in production, the cost of feeds takes up 54-63% of operating costs when stocking density is increased such as in the semi-intensive and intensive farming methods. In mudcrab culture, costs of feeds is 50-57% of operating expenses while in milkfish culture, the costs of feeds comprise 10-77% of total costs. Hence, an evaluation of feed quality and economic efficiency is a very important undertaking to determine the profitability of an aquaculture venture.

This chapter aims to introduce concepts and methods in doing economic analysis applicable in aquaculture in general with emphasis in feed production and feeding in aquaculture farms. This chapter discusses the following topics: cost of producing feeds; simple single-input (feeds) and single output (fish) production function; indices for measuring economic efficiency of feeds; the least-cost combination; and linear programming as used in the allocation of limited resources such as feed ingredients that will meet the nutritional requirements of the fish.

Cost of producing feeds

The cost items in producing aquaculture feeds can be classified into direct costs and indirect costs. Direct costs include the raw materials such as fishmeal, mineral and vitamin mixes, and other ingredients, and direct labor used in the manufacture of the feeds. The direct materials become part of the final products in the form of feeds. Direct labor cost items include wages and salaries of the workers that manufacture the feeds.

Indirect costs include (1) supervisory and management overhead expenses; (2) electricity; (3) supplies other than feed ingredients such as gasoline and machine oil, if any; (4) repair and maintenance; (5)

depreciation of fixed assets such as equipment, buildings; and (6) other incidental expenses required in manufacturing the feed. The cost of packaging and storage of the feeds is not included in the computation.

Depreciation is the allocation of the original cost of all fixed assets over their economic or useful life. For example, if a feed mill costs P1,000,000 and will be economically useful for ten years, the depreciation is computed by dividing P1,000,000 over 10 years, which is equal to P100,000. It is a non-cash expense because the money for constructing or purchasing a fixed asset such as a feed mill has been used up but is being allocated over the period of its useful life.

Table 8.1 shows a list of cost items in producing shrimp diet. The direct cost of ingredients comprises 92% of the total cost of producing feeds.

The cost of direct labor used in grinding, pulverizing, mixing, pelletizing, and oven drying is computed by multiplying the number (2) of workers with the wage rate (P200 per day) for example which is equal to P400. The cost of electricity is computed by multiplying the number of hours used (200-kilowatt hour) with the cost (P2.50 per kwh) which is equal to P500.

The total cost of producing one ton of shrimp feeds which amounted to P25,293.83 is the sum of the direct cost (ingredients and direct labor) and the indirect cost or P25.29 per kg.

Table 8.1 Production cost of shrimp diet

Item	Quantity	Unit cost per kg	Cost/kg	Cost/ton
A Ingredients	Composition (%)	(in Philippine Peso)		
Fish meal	25.00	25.00	6.2500	
Soybean meal	25.00	11.25	2.8125	
Shrimp head meal	15.00	21.00	3.1500	
Bread flour	16.00	8.60	1.3760	
Rice bran	3.95	4.96	0.1959	
Seaweeds	5.00	12.00	0.6000	
Cod liver oil	2.50	84.79	2.1198	
Soybean oil	2.50	45.00	1.1250	
Vitamin mix	2.00	200.00	4.0000	
Mineral mix	1.00	130.00	1.3000	
Dicalphos	2.00	14.00	0.2800	
Ethoxyquin	0.05	8.00	0.0040	
Subtotal	100.00	232.132	23.2132	
B. Direct labor (grinding, pulverizing, mixing, pelletizing, oven drying)		2 aides	200.00	400.00
C. Overhead				
Electricity (200 kwh)			2.5	500.00
Miscellaneous (5% of Items A & B)				1,180.66
Subtotal				1,680.66
D. Cost per ton				25,293.83
E. Cost per kg				25.29

Source: Millamena 1994

Single-input and single-output production function

The previous section discussed simple methods of computing the production cost of feeds using several inputs. Feeds, in turn, are one of the inputs in producing fish. This chapter describes an economic method of evaluating the relationship between the inputs used to produce a particular output. This method is called production function. Production function is defined as the technical relationship between the farm inputs and the output at a given time using a technology. Simply stated, the total yield or output varies with the quantities and combination of inputs used in the production process. The fish grower or the management of corporate farms decides what, how, when, and how much to produce from the limited resources of the company.

In aquaculture, farm inputs are generally comprised of fry or fingerlings, feed, fertilizers, chemicals, labor, as well as technical and management services. The desired output is the marketable-size fish.

For example, the relationship between the various inputs, denoted as $X_1,...X_n$, and an output, denoted as Y, is expressed in the following equation:

$$Y = f(X_1,X_2,X_3,X_4,X_5,...X_n)$$

where:

Y = total fish yield (output)
X_1 = amount of feed
X_2 = stocking size of fingerlings
X_3 = amount of fertilizer
X_4 = stocking density
X_5 = amount of labor
X_n = other variables related to growth of fish and total yield

The mathematical expression shows that the fish yield (Y) is related or is a "function" of the variables or production inputs ($X_1,...X_n$) in some particular way. The purpose of the production function analysis is to estimate the physical and marginal relationships between output (dependent variable) and a number of inputs (independent variables). The inputs or independent variables that significantly influence the yield are included in the production function. There may be other inputs that are used but their marginal influence on fish production is not significant.

A simple input (feed) and single output (fish) production function (Shang 1990) is shown in Table 8.2. The level of feeding given to the fish is represented by Y_1 and the output or the level of the total physical product (TPP) is represented by Y. The Y or TPP increases up to a certain level as the level of X_1 (feed) increases. The highest level of output of production is 69 units. This output level is attained when feeding level is 11 units. This production level is called the maximum sustainable yield (MSY). The yield or TPP starts to decrease beyond this feeding level. Therefore, there is no reason or logic in increasing the level of input when MSY has been attained. There is no additional benefit in giving additional feeds to the fish beyond the MSY.

The average physical product (APP) is the amount of fish produced per unit of input (feed) given to the fish. It is computed by dividing the total physical product (TPP) over the level of X_1 (feed). The marginal physical product (MPP) is defined as the increment or the change in output (fish) resulting from one additional unit of input (feed) given the fish.

Table 8. 2. Relationship among total physical product, average physical product, and marginal product

Level of X_1 combined with mixed resources	Level of total physical product (Y) (TPP)	Average physical product (APP)	Marginal physical product (MPP)
0	0		
			0.5
1	0.5	0.5	
			1.5
2	2	1	
			3
3	5	1.67	
			7
4	12	3	
			11
5	23	4.6	
			16
6	39	6.5	
			13
7	52	7.43	
			8
8	60	7.5	
			5
9	65	7.22	
			3
10	68	6.8	
			1
11	69	6.27	
			-1
12	68	5.67	
			-3
13	65	5	
			-5
14	60	4.29	

Source: Shang 1990

Graphically, the relationship among TPP, APP and MPP to the yield or level of output Y, and level of input (X_1,...X_n) is shown in Figure 8.1. The graph can be divided into three stages. In Stage I, TPP, APP and MPP exhibit increasing returns. Furthermore, the TPP increases at an increasing rate. MPP increases until marginal increment per unit is at its peak. APP continues to increase. Stage II is the phase where diminishing returns occurs. MPP decreases for every additional unit of input (feed) given to the fish. At this stage, TPP is still increasing although at a declining rate. The peak of the TPP is the maximum sustainable yield (MSY) or the point where there is no longer an increase of production in spite of the introduction of an additional unit of input (feed) into the fish culture system. At this point the MPP is zero. APP is still increasing but begins to decline. Beyond this point is Stage III or the declining phase. There is no longer an advantage of providing an additional input because there will be a decrease in the output or production yield. This means that feeding the fish at this stage will result to decrease in fish production.

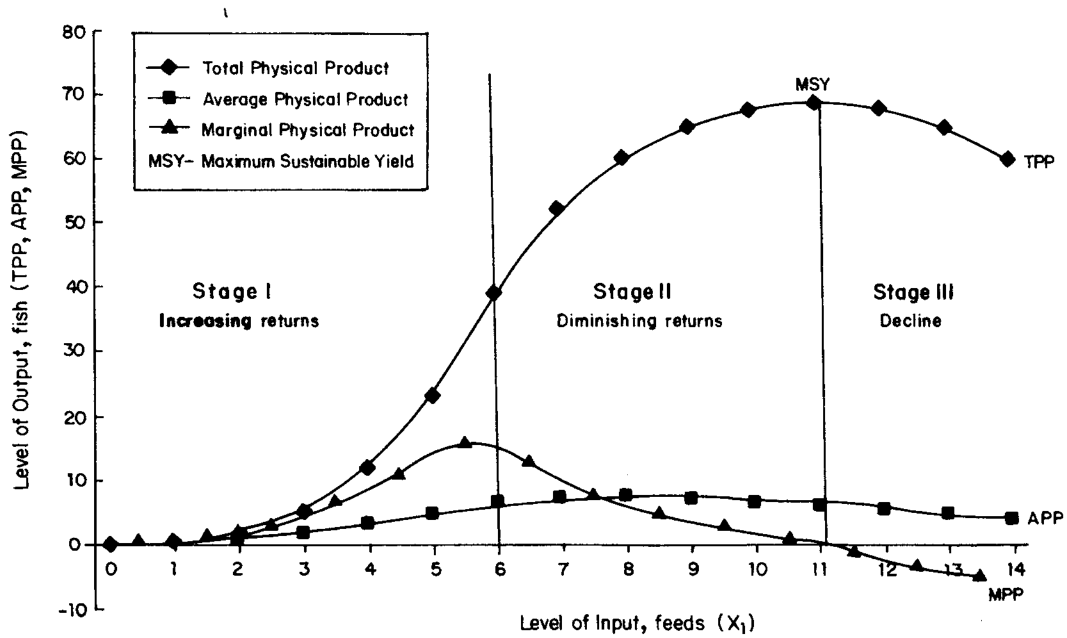

Figure 8.1
Relationship between TPP, APP, and MPP.

The production function and the cost of production

The introduction of cost in production analysis is an economic tool that can guide the fish farmer in his decisions related to production. The main objective in production analysis is to maximize profit. What level of production will result to maximum profit given a level of resources such as feed? If a fish farmer will base his decision on the production function discussed earlier, he may be tempted to maximize production up to the MSY (Table 8. 3 and Figure 8.2) or where the production output is at the maximum. However, this section will show that the fish farmer should consider the economic profit that could be attained at various levels of input.

Let us define some new terms at this point.

- Value of TPP (VTP) is the monetary value of the output (fish) based on the farm gate prices or prices of the produce sold in the farm. As an example, Table 8.3 assumed that the price of one unit of output is equivalent to one peso (P1.00).
- Value of APP (VAP) is APP multiplied by the farm gate price.
- Value of MPP (VMP) is the additional revenue or sales resulting from an increase in additional unit of input.

- Total variable input cost (TVIC) is the sum of the cost of the variable input (feed) at the different levels of input.
- Profit is the difference between the VTP or gross revenue and the TVIC or input cost.

The last column of Table 8.3 shows the highest profit level is 20 units which is attained at the feeding level of 8 units and the corresponding yield is 60 units. This point is the maximum economic yield (MEY). Figure 8.2 illustrates the relationship between MEY and other cost and revenue variables. VTP or the value of the total product is the revenue curve. The TIC is the cost curve. The shaded area is the profit area where the difference between the revenue and the cost are positive. The biggest difference between the two curves is at the MEY. The MEY is reached before the point where maximum yield or the MSY is attained. Therefore, with profit as the main objective, the desired feeding level should be at the MEY where it is most cost efficient. At feeding levels beyond the MEY, there is no additional or marginal economic benefit in inputting additional unit of feed since the additional cost of feed will be greater than the additional income derived from the additional output.

There are two conclusions that can be derived from Table 8.3 and Figure 8.2;

1. maximizing farm production does not always maximize profits;
2. decision on maximizing profit is based on marginal analysis or on whether there is additional benefit from additional input (feed).

Economic Efficiency of Feeds

The usual practice in measuring the efficiency of formulated feeds is to measure the feed conversion ratio (FCR). FCR is defined as the total amount of feeds by weight given over a certain period divided by the yield in kilograms. The lower the ratio, the more efficient the feed, regardless of the cost.

FCR, however, does not take into account the cost of feeds and the economic efficiency of using feeds. A method of measuring cost efficiency of feeds called the incidence cost, indicates the cost of producing a unit (by weight) of fish.

$$\text{Incidence cost} = \frac{\text{total cost of feed used}}{\text{wt of the fish produced}}$$

In comparing two feed formulations available to a fish farmer, the feed with a lower incidence cost is more economically efficient and, therefore, more beneficial to the farmer.

Another method of measuring economic efficiency of feeds is to look at the value of the fish produced and the cost of feeding. This is called the profit index, which indicates the profit for every unit cost of feeds incurred. This is computed using the following formula;

$$\text{Profit index} = \frac{\text{total value of the fish produced - total cost of feeds}}{\text{total cost of feeds}}$$

Table 8.3 Relationship among total physical product, average physical product, marginal physical product, value of total physical product, value of average physical product, value of marginal physical product, total variable input cost, and profit.

Level of X_1 combined with mixed resources	Level of total physical product (Y) (TPP)	Average physical product (APP)	Marginal Physical Product (MPP)	Value of TPP (TPPx1)	Value of APP (APPx1)	Value of MPP (MPPx1)	Total variable input cost (X_1x5)	Average variable input cost (APPx5)	Marginal variable input cost (MPPx5)	Profit (TVP-TVIC)
0	0			0			0			0
			0.5			0.5			0	
1	0.5	0.5		0.5	0.5		5	2.5		-4.5
			1.5			1.5			7.5	
2	2	1		2	1		10	5		-8
			3			3			15	
3	5	1.67		5	1.67		15	8.35		-10
			7			7			35	
4	12	3		12	3		20	15		-8
			11			11			55	
5	23	4.6		23	4.6		25	23		-2
			16			16			80	
6	39	6.5		39	6.5		30	32.5		9
			13			13			65	
7	52	7.43		52	7.43		35	37.15		17
			8			8			40	
8	60	7.5		60	7.5		40	37.5		20
			5			5			25	
9	65	7.22		65	7.22		45	36.1		20
			3			3			15	
10	68	6.8		68	6.8		50	34		18
			1			1			5	
11	69	6.27		69	6.27		55	31.35		14
			-1			-1			-5	
12	68	5.67		68	5.67		60	28.35		8
			-3			-3			-15	
13	65	5		65	5		65	25		0
			-5			-5			-25	
14	60	4.29		60	4.29					60

Source: Shang 1990

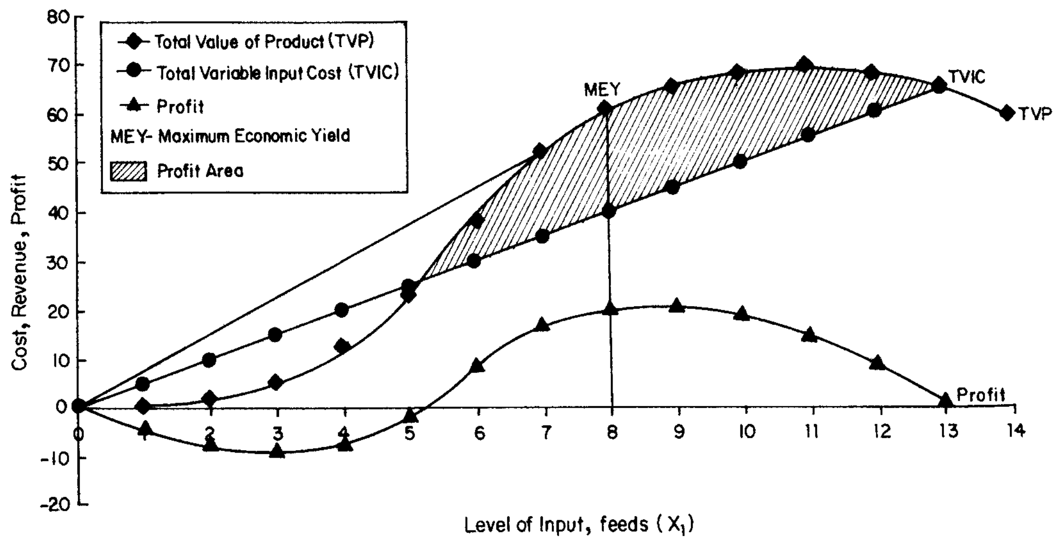

Figure 8.2
Relationship between TVP, TVIC and profit.

The total value of the fish does not only consider the weight but also the overall quality including freshness of the fish. The value attributed to quality is accounted in the market price of the fish. These factors are included in the profit index. The farmer can then compare the profit index of various feeds when choosing feeds for his stock.

A third indicator of determining the economic efficiency of feeds is the returns on feeds. This indicator shows the rate of return on investment on feeds. This is measured by the following formula;

$$\text{Returns on feeds} = \frac{\text{net profit}}{\text{cost of feeds}}$$

Table 8.4 is a cost and returns computations that shows the comparative economic efficiencies based on the three indicators (incidence cost, profit index, and return on feeds) in the pen culture of Asian catfish (*Clarias macrocephalus*) fed three different types of diets. Using the aforementioned formulas, the summary of the economic indicators using the three diets is:

Diet 3 and Diet 2 have lower incidence costs, higher profit indexes, and returns on feeds compared to Diet 1. We conclude that the use of Diets 3 and 2 are economically viable. The use of Diet 1 is a losing proposition.

Table 8.4 Cost and returns of the pen culture of *Clarias macrocephalus* at a stocking density of 10 fish/m² and fed three different diets for 120 days. Values are on a per ha per crop basis in Philippine Peso (PhP)*

Items Revenue	Quantity (kg)	Unit Price	Diet 1	Diet 2	Diet 3
Diet 1 (30.2 g MBW)	2208	120	264960		
Diet 2 (58.3 g MBW)	4696	120		563520	
Diet 3 (67.35 g MBW)	4808	120			576960
Less:					
Variable costs					
Fingerlings (pcs)	100000	1.5	150000	150000	150000
Feeds (kg) Diet 1	6308	14.69	92665		
Diet 2	9979	15.4		153677	
Diet 3	21964	7			153748
Lime (ton)	1	1000	1000	1000	1000
chicken manure (ton)	1	800	800	800	800
45-0-0 (bag)	0.5	415	207.5	207.5	207.5
16-20-0 (bag)	1	410	410	410	410
Diesel fuel (l)	100	15.15	1515	1515	1515
Miscellaneous expenses			5299.2	11270.4	11539.2
Repair and maintenance			598.8	598.8	598.8
Caretaker's salary (mo)	5	1000	5000	5000	5000
Pond rent (yr)	0.5	8000	4000	4000	4000
Subtotal			**261495**	**328478**	**328819**
Fixed cost					
Depreciation			2649	12849	12849
Interest expenses			12849	15595	15598
Subtotal			**15498**	**28444**	**28447**
Total costs			**276993**	**356922**	**357266**
Net profit before tax/crop			**-12033**	**206598**	**219694**
Incidence cost = $\frac{\text{total cost of feed used}}{\text{wt of the fish produced}}$ =			**41.97**	**32.73**	**31.98**
Profit index = $\frac{\text{total value of fish - total cost of feeds}}{\text{total cost of feeds}}$ =			**1.86**	**2.67**	**2.75**
Returns on feeds = $\frac{\text{net profit}}{\text{cost of feeds}}$ =			**-12.99%**	**134.44%**	**142.89%**

Source: Coniza et al. 2001

Least-cost Combination of Feeds

Considering the sensitivity of the cost of feeds in the profitability of fish farming, keeping the cost down is crucial to ensure the economic viability of the fish farming enterprise. Least-cost combination techniques are used in determining the lowest cost from different feed combinations that would result in the same production.

For example, two types of feeds (F_1 and F_2) are sold at different prices and are available to the fish farmer. If the two types of feeds can be substituted, the rate of substitution indicates the amount by which one feed must be changed in order to offset the change in the amount of the other feed. This is called marginal rate of substitution (MRS) between feeds, the value of which is negative.

$$\text{MRS} = \frac{\text{amount of feed replaced } (F_1)}{\text{amount of feed added } (F_2)}$$

The MRS between inputs (feeds) is a physical relationship and cannot determine the least-cost combination of feeds. Feed prices (prices of PF_1 and PF_2) are needed and the ratio is compared with MRS.

$$\text{Price ratio} = \frac{\text{price of feed added } (PF_2)}{\text{price of feed replaced } (PF_1)}$$

The least-cost combination of feeds F_1 and F_2 occurs when the MRS is equal to the inverse of the price ratio.

$$\frac{F_1}{F_2} = \frac{PF_2}{PF_1} \quad \text{or} \quad F_1\,(PF_1) = F_2\,(PF_2)$$

The cost of change in one feed is equal to the cost of change in the other feed. In Table 8.5, the least cost combination of feeds is at P180, which corresponds with the use of 10 parts of F_2 and 15 parts of F_1. In this connection, the cost of change in F_1 is equal to the cost of change in F_2.

Table 8.5 Hypothetical relationship for combining feeds to produce a given level of output (P_1 = P9, P_2 = P6)

X_2	X_1	F_1/F_2 (MRS*)	P_2/P_1	Cost ($F_1 x P_1 + F_2 x P_2$)
0	40		240	
4	24	0.25	0.67	180
10	15	0.67	0.67	180
15	8	0.71	0.67	183
20	3	1.00	0.67	198
25	0	1.67	0.67	225

*Marginal rate of substitution
X_1 is the feed being replaced
X_2 is the feed being added
F_1 is the change in the quantity of X_1
F_2 is the change in the quantity of X_2

Source: Shang 1990

Minimum Cost of Feed Formulation using Linear Programming

Linear programming is a computational method used to allocate scarce resources to maximize profit or minimize cost. In aquaculture, it is often used in the minimization model of computing the least-cost feed combinations or ration and still meet the required nutrients for the fish. The concepts involved in linear programming include:

- Objective – usually to maximize profits or minimize cost;
- Constraints – resources such as raw feed ingredients are restricted or limited;
- Alternative ways of attaining the objective are determined;
- Relationship between input and output is assumed to be linear;
- Prices paid or received are assumed constant; and
- Quantity of inputs used should be equal to or less than the quantity available.

Table 8.6 presents a hypothetical example that illustrates the data on nutrient availability, cost, requirements, objectives, and constraints to consider in computing for least cost combination using linear programming as adopted from Shang 1990.

Table 8.6 Data on nutrient availability and requirements, feed cost, objective, and constraints in linear programming

	Nutrient		Feed A	Feed B	Minimum daily requirement
A.	Nutrient availability and requirements (Unit of nutrient per unit of feed)				
	Calcium		2	1	18
	Protein		2	2	20
	Calories		1	5	25
B.	Cost per unit of feed		1.00	2.00	
C.	Objective: Minimize cost =	$P_1A + P_2B$			
D.	Subject to constraints such as:	2A + 1B => 18			
		2A + 2B => 20			
		1A + 5B => 25			
		A=>0, B=>0			

where: A, is the amount of Feed A, and
B, is the amount of Feed B.

Source: Shang 1990

The constraints in the equations in Table 8.5 insure that the minimum requirement for ingredient is met at the least cost. For example, the minimum units of calcium, protein and calories are 18, 20, and 25 respectively. Simple linear programming can be solved graphically. But as the problem becomes more complicated, systematic computational techniques using computers are required.

Summary

The concepts and approaches on the evaluation and computation of selected indicators of the economic efficiency of feeding in aquaculture operations are discussed. The discussion started with the identification of cost items involved in producing aquaculture feeds. These cost items are classified into direct costs and indirect costs. Total costs and per unit costs are useful economic indicators to guide the aquaculture farmers in their operations.

This chapter introduced the production function approach for evaluating the relationship between farm inputs such as feeds, and output (fish). Quantitative examples demonstrated marginal analysis that provided basis for understanding the various stages in production systems. These are the stages where profit is increasing, maximum, or decreasing. The concepts of maximum sustainable yield (MSY) and maximum economic yield (MEY) were discussed in order to highlight the optimum feeding level that will result to the highest profit level.

This chapter also presented indices for measuring the economic efficiency in producing feeds. These indices include incidence cost and profit index. The least-cost approach was discussed to demonstrate the method of determining combinations of ingredients of different feed formulations given the prevailing prices.

Finally, the chapter introduced the concept of linear programming in determining the minimum feed cost that would yield the desired levels of nutrients required by the fish.

Guide Questions

1. What items comprise the direct costs of producing shrimp feeds?
2. What items comprise the indirect costs of producing shrimp feeds?
3. In terms of yield levels, at what point is additional feeding no longer beneficial to the fish farmer? What is the most profitable level of feeding the fish? Explain using concepts of marginal analysis.
4. How do you measure the economic efficiencies of different feeds available to the fish farmer?
5. What is linear programming?
6. What are the concepts and requirements in linear programming and analysis of feed formulations?

Suggested Readings

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