AQUACULTURE EUROPE '89 - BUSINESS JOINS SCIENCE
N. De Pauw and R. Billard (Eds). European Aquaculture Society.
Special Publication No.12, Bredene, Belgium (1990).

Aquaculture economics: identification and management of production costs

Report of the panel session held during "Aquaculture Europe '89", Bordeaux, France, October 2-4, 1989

Moderators: D. Bailly[1] and P. Lagos[2]
[1]IFREMER, Paris, France
[2]Cephalonian Fisheries Ltd, Athens, Greece

Panel members: L. Chim[1] , M. Horne[2], and S. Shaw[3]
[1]France Aquaculture, Brest, France
[2]Stirling Diagnostic, Stirling, Scotland, United Kingdom
[3]University of Stirling, Stirling, Scotland, United Kingdom

Production costs: definitions (D. Bailly)

As an introduction to the panel session the basic structure of the production costs and definitions were reviewed. Basically the production costs are all the expenses incurred during the production process and, subtracted from the turnover (sales), they determine the income before taxes. Their amount results from a combination of technical and commercial choices. Technical choices (production process) determine the needs for the inputs (quantities of feed, juveniles, labour, loans, ...) and the commercial choices the amount of money to be spent on it according to the price of each item, including the interest which is the price of money. In the same manner technical choices determine the level of production and commercial strategy the value of the production. The total cost per unit produced (kg of fish), and the breakdown of this total cost are good criteria, among others, to compare the production from different systems, different scales or different areas, and thus judge their competitiveness. In the case of combined productions (two or more different species and/or sales at different stages) the accounting of the costs and income must be analytical, i.e. divided according to the contribution in each production. To be considered as one production is the process that leads to one product to be sold on a market.

The accounting of production costs has the following structure:

- investment expenditures: every year the depreciation is calculated on the basis of the initial value and an estimation of the life span of each item of the fixed assets;
- operation expenditures: 1) intermediary consumptions disappearing during the production

process (juveniles, feed, energy, packing-cases, ...); 2) labour cost; 3) taxes; 4) services (repair and maintenance, transportation, insurance, ...); and 5) general expenses;

- financial expenditures: the interests paid on short- or long-term loans contracted to finance part of the investment or operation expenditures.

Production costs are often referred to as fixed (or non-proportional) costs and variable (or proportional) costs. Are considered as fixed, the costs determined by the installed capacity of the farm. The variable costs vary according to the actual level of production. In the case of aquaculture feed and juveniles are the basic variable costs. Depreciation, interest, energy, and general expenses are often the main fixed costs. Labour is theoretically considered as a variable cost, but in small farms employing mainly permanent workers, labour may sometimes be considered as a fixed cost. More than the definition, what is important in this breakdown of the costs is that fixed costs must be considered very carefully when the production capacity of a farm is not fully utilized, as their weight may quickly offset the overall profitability.

To know the production costs and their evolution is essential to the management of a farm. It shows the main items on which the cost reduction is worth an effort. It helps the manager for decision making and adjustment to changes. It also gives the price level under which the product cannot be sold without losses.

It was observed in aquaculture projects that some costs are often under evaluated, or even omitted. More attention should be given to financial expenditures, general expenses, conditioning and transportation of the product, insurance cost and expenses related to the control of water quality.

A case study: production costs and the integrated marine fish farm development (P. Lagos)

A stage theory of growth applying in a commercial bream and/or bass fish farming operation was proposed 2 years ago in the same forum by P. Lagos. He had selected as a case study the Cephalonian Fisheries operation because, at that time, it was the only private integrated farm of a sizable operation and also because he had closely followed the development of this farm. Since then there has been no change in this field, except that more units are in operation now around the Mediterranean basin, and many more at the project stage. What has changed though for the Cephalonian Fisheries are the detailed characteristics of what he called in Amsterdam the "dreams come true stage", or the moment when profit, the dream of every entrepreneur, comes true as a result of day to day decisions to manage the costs, representing the hard reality.

Table I presents a typical profit and loss account of an integrated fish farm for a total production of 1.4 million fry (including 200000 sold at US\$1.07 per unit for bream and US\$0.84 per unit for bass), and 340t fish (156t bream and 184t bass sold at an average price of US\$16.47.kg^{-1}). Depreciation is based on a total investment of US\$3.7 million over the last 10 years. Finance expenses include US\$173400 annuity for a long-term hatchery

Table I. Profit-loss statement of an integrated bream/bass farm (values: xUS$1000)

Item	Hatchery	Ongrowing	Total
Quantities produced	1400000 fry		
Quantities sold	200000 fry	340t	
Sales	196.5	5300.3	5496.8
Inventory variation	0.0	39.1	
Affected costs			
Operation costs	442.3	1593.2	
Depreciation	142.4	172.0	
Financial expenses	278.2	188.3	
1.2 million juveniles	- 739.7	739.7	
Total affected costs (for quantities sold)	123.3	2654.8	2778.0
Marketing and general expenditures			
Marketing			265.3
Administration			405.5
Others			55.2
Provision			99.8
Investment replacement			102.3
Taxable income			1790.7
Affected cost per unit	($/fry) 0.616	($.kg^{-1}) 7.81	
General exp. per unit[1]	($/fry) 0.115	($.kg^{-1}) 1.29	
Total cost per unit	($/fry) 0.731	($.kg^{-1}) 9.10	

[1] 40% of administrative and other expenses for fry.

investment loan of US$0.6 million, and US$115600 annuity for a long-term ongrowing investment loan of US$0.5 million. The remaining represents the cost of short-term financing of operation expenditures: US$0.52 per unit at hatchery stage and US$1.16 per unit for ongrowing fish stock.

Table II gives the detail of operation costs of the farm. The feed for ongrowing includes 930t of feed at US$1.2.kg^{-1}. Other raw materials are mainly pharmaceuticals and chemicals. The labour cost in the hatchery represents the salaries of 14 persons, including five scientists, and labour on the ongrowing site 28 persons, including three scientists.

Table II. Operation costs of an integrated bream/bass unit (values: xUS$1000)

Item	Hatchery	Ongrowing
Feed	97.7	1118.1
Other raw material	1.9	
Labour	234.2	250.8
Energy	59.2	
Other variable expenses	10.3	10.9
Other fixed expenses	34.6	40.4
Rents		3.1
Insurance	4.1	169.7
Total	442.0	1593.0
Operation costs per unit	($/fry) 0.616	($.kg^{-1}) 7.81

P. Lagos concludes his contribution with four general remarks open for discussion:

1) We cannot refer to intensive aquaculture as a method for producing "cheap fish". Intensive production of fish is an expensive process, especially in the case of fry production.
2) Intensive aquaculture can be a profitable business, but it is always a risky one.
3) Commercial hatchery operation does not seem to be viable in Greece since it cannot compete with hatchery selling fry from natural spawning (average production cost: 0.45$/fry).
4) Market for bass/bream is and will remain very stable for the next 5 or 6 years, sustaining high prices. However, massive production will only be economically feasible if cost is reduced to US$6.00, and bass/bream enters the catering business.

Economies of scale and salmon aquaculture (S. Shaw)

The objective of this contribution is to suggest a need to consider the concept of economies of scale in aquaculture in a disaggregated way and a need for caution in its use as a measure of efficiency or survival potential. Economies of scale are defined as "the effect on average costs of production of different rates of output, per unit of time, of a given commodity, when all possible adaptations have been carried out to make production at each scale as efficient as possible" (Silberston, 1972). They are classified as: 1) the production economies at the level of the plant-economies in use of labour, of increased dimensions or of massed reserves; and 2) the economies of the business, including "real economies" - economies of replication, in the use of labour, marketing, transport or storage - and pecuniary economies associated with increased market power.

MEASURING ECONOMIES OF SCALE IN SALMON AQUACULTURE

Findings for the annual surveys of the Norwegian Directorate of Fisheries suggest that production costs per site decline with increased output. Björndal (1987), citing 1984 data, shows a decline in total costs from NKr33.87.kg^{-1} at an output of 28t to NKr30.74.kg^{-1} at an output of 141t. The main causes are savings in variable costs, in particular in costs of labour and in the purchase of smolts.

Shaw (1989) has estimated plant economics using engineering cost data. Assuming constant prices for inputs, costs per kilo fall from £3.86.kg^{-1} at a size of 50t to £3.03.kg^{-1} at 200t to £2.81.kg^{-1} at a plant size of 500t, with the economies mainly in the use of labour and in the capital costs.

Both studies suggest that the biggest gains are in scaling up from less than 50t to 100-200t (around 20% cost reduction from 50 to 200t). Subsequent gains are more modest (around 7% from 200 to 500t).

For economies in the operation of businesses, we can only judge from looking at the change in business structures as production levels have increased. In Scotland the trend has been towards increased size of operations. Industry sources suggest that from over 90 selling points 2 years ago, 80 to 90% of production is now in the hands of 8 or 9 companies. Marine Harvest, the market leader now, markets over 10000t of product and there are a number of companies marketing over 3000t. This is consistent with a view that the advantages of size to an aquaculture business are significant. There are a priori reasons why this is plausible:

1) Advantages of bulk buying of feed, smolts, and other inputs occur to the business rather than to the site.
2) Marketing economies which both reduce costs of marketing and allow the business to compete in a cost effective way in the markets which demand continuity of supply and consistency of quality and sales volume.
3) The advantages of specialization in use of labour and ability to employ specialists occur at the level of the business (employment of marketing and technical specialists) as well as at the level of the site.

Size has been achieved by multi-site operations. It has also been achieved by the formation of marketing groups, where the output of farmers is marketed collectively. This suggests that economies at the level of the business are the most significant and that small size of operation at the site level is less disadvantageous than small size at business level.

DISCUSSION AND CONCLUSION

The purpose here is to argue that it is necessary to identify and distinguish different types of economies. The tentative evidence above that economies of scale appear to be more important at the level of the business than at the level of the site supports this view. A simple example using the data above reinforces this conclusion. Björndal suggests that the reduction in smolt costs through larger scale buying could be around 25%. Industry sources give examples of where the formation of feed buying groups can reduce the costs of feed by up to 10%. Together feed costs and smolt costs represent around 55% of total costs. Using the Shaw data, these savings would reduce the average costs of production of a 200t operation, which was a member of a buying/marketing group, to around £2.77.kg^{-1}. The costs of a farmer who is part of a group can then be compared with those of a larger site operator (500t) who is no part of a group and has no access to bulk discounts (Table III).

If we broaden the discussion to a consideration of the role of scale economies as predictor of survival of particular sizes of site or business, the need to be very specific is again shown. Many of the capital assets of fish farms such as access roads, piers, and buildings, have very long lives. If they are fully depreciated, the effective costs of operations will be below those of more recently established larger sites where this is not the case. Indeed, there is some tentative evidence (industry sources) that the businesses in the most difficulty during the current excess capacity situation are those companies who have recently expanded to around the 200-500t range and have heavy debts. Many of the smaller older farms appear to be managing somewhat better because they do not have a heavy burden of debt finance. There is a further difficulty in that the engineering type estimates discussed above do not allow for management quality. It is often argued that standards of husbandry may be higher with consequent lower mortalities and better food conversion ratios in smaller farms (and businesses) because of the close involvement of the owner in site operations. This would help to offset any economies of larger sites or multi-plant businesses.

Because of the immature state of the industry it is difficult to form conclusions about where the scale economies occur and where they are most important. Are the main sources pecuniary economies, economies in marketing or production economies associated with multi-site operations? Can marketing economies and integration of management of multi-sites be separate or do the two have to be managed within the same organization for maximum effectiveness? More years of experience will be needed before these questions can be fully answered.

The costs and water quality control in shrimp aquaculture (L. Chim)

In pond culture the importance of water quality control is linked to the intenseness of the

Table III. Sensitivity of costs to changing input prices

Size of operation (t)	50	200	500
Costs per kg:			
Without buying economies	£3.86	£3.03	£2.81
With buying economies	£3.60	£2.77	£2.57

culture system. With an intensive system the costs related to the water control increase (energy, investment, ...), but productivity also increases, mainly as a consequence of the economies of scale on non-proportional costs. Comparing the average production costs among different systems, the balance may be in favour of a more or less intensive system. In the case of shrimp culture we can define three types of culture systems (Table IV).

Environment of type 1 is found with extensive systems. Water management is very limited with a maximum of 2% daily exchange of water, generally through the action of the tide. The production cannot be more than 300kg.ha^{-1} per cycle. The environment of semi-intensive systems may be of type 1 or 2. Due to the increase of the biomass, and the drop in oxygen concentration (less than 3ppm), the water must be renewed at a rate of 20%.d^{-1} for a biomass of 100g.ha^{-1}. The average production is 1000kg.ha^{-1} per cycle. Intensive systems start with the type 2, until the extreme of type 3. With a biomass of over 100g.ha^{-1}, the concentration of ammonia also affects the culture. This type of environment can be controlled through quick and mass water exchange (400%.d^{-1} for the Shigeno system in Japan), or through the development of nitrifying bacteria with a limited exchange of water and oxygenation. This is the case of the culture system developed by Aquacop in Tahiti. The production can reach 20t.yr^{-1}, and, although there is no detailed comparative study, it seems to be more economical than the Shigeno system.

Some of the costs can be totally or partially affected by the need for water quality control. Pumping station, aerators, water distribution channels (investment costs), and energy (operation costs) are totally related to the water quality control. Part of the costs involved in ponds, feed, and labour is also related to it. For a given production capacity the cost of pond construction will increase when the size of each pond decreases. But the water quality control is more efficient in smaller ponds, and thus productivity can be better. Ponds for semi-intensive culture may cover 10-20ha, whereas intensive culture ponds cover only 0.5-5ha. Due to feeding habits of the shrimp (slow consumption) and to avoid pollution of the water, artificial feed used in an intensive system must be very stable in the water. The use of special binding material and process generates higher costs. The monitoring of water quality requires specialized labour. Based on this the share of the global production costs related to the water quality management can be evaluated. Such an evaluation is proposed here for the case of the Aquacop super-intensive system (Table V).

Table IV. Environmental factors affecting growth and survival in shrimp culture according to the biomass, and their relation to the water control

Environment type	Biomass g.ha^{-1}	O_2	NH_4-N	Water control
1	10-30	-	-	Minimum (water exchange rate 2%.d^{-1})
2	50-100	Limitative	-	Pumping (water exchange rate 5-20%.d^{-1})
3	>100	Limitative	Limitative	Pumping: 10-400%.d^{-1} + aeration 20HP.ha^{-1}

Table V. Breakdown of the total production cost for shrimp production (IFREMER. COP) and evaluation of water quality control related costs

Cost	Total %	Related to water quality control (pers. estim.) %
Labour	34	15
Feed	23	1
Depreciation	16	8-10
Postlarvae	7	0
General expenses	9	0
Aeration	8	8
Pumping	3	3
Total	100	35-37

In the case of intensive culture, the water quality control generally accounts for 30 to 40% of the total cost. This is at least as important as postlarvae, labour, and feed, which are often considered as the main costs. This cost is distributed among various items and is not estimated. Its estimation can help rationalization and reduction of the total costs.

The cost of disease in intensive salmonid aquaculture (M. Horne)

The continued growth of aquaculture, ahead of the rate of market uptake, is bringing increased competition to bear and pressure on prices. It is therefore important that all of the costs of an operation should be identified and efforts made to minimize these where opportunities arise.

Expenditure on disease is one of the smallest items over the two-year salmon cycle and yet it is one of the major preoccupations of on-site farm management. This is because each year, at best, disease wastes a significant proportion of the crop (in 1988, 25% of the Scottish salmon crop was lost due to furunculosis), at worst it can close a farm completely. At the same time it is a tangible, accessible area where the efforts of local management can be directed to improve profitability.

Disease losses vary enormously and are readily quantified financially. However, less obvious results of disease are frequently the more costly. Table VI lists some of these. particularly significant are the market losses which, in a competitive industry, may threaten the viability of a business.

Technologies are increasingly available to assist in disease control. Vaccines against the commoner bacterial diseases are in wide use and anti-viral vaccines are under development. Diagnostic tests which give early warning and confirmation of disease have recently been

Table VI. Causes of financial loss from disease

Direct	Mortalities	
	Closure order on site	
	Restriction of movement order	
	Unavailability of replacement stock	
Market losses	Restricted market for some diseased stocks	
	Reduced growth rate:	- lower yield
		- missed market
	Withdrawal period for treated fish - missed market	
	Reduced quality of survivors	
Lost opportunity	Reduced stocking density to minimize loss	
	Diversion of management and labour	
	Underutilization of facility	

introduced and, when EC disease control regulations are in place, will be essential to police the transportation of eggs, fish, and some fish products. When prevention fails and disease occurs, therapeutics are available to control the outbreaks in some cases.

All of these technologies have their place and are of comparable cost effectiveness. At current prices, vaccine for a tonne of salmon costs less than 0.5% of Farm Gate Value (FGV), a disease monitoring programme of a 100-t unit costs approximately 1% of the FGV, and a season's use of antibiotics varies in cost between 0.7% and 2% of the FGV. (Table VII, Tabel VIII, and Table IX).

These values indicate the small target savings required to justify the cost of proper disease control programmes and offer local management accessible opportunities to improve efficiency and quality in a less pioneering, more mature modern industry.

Discussion with the floor

The discussion opened with a question concerning the relation between water management and scale of production. No specific study has been conducted on this aspect. Water quality is one of the main factors for the choice of the site. Thereby it often influences the overall production cost. Location may not be close from markets or the investment may be high due to uneasy access. As the number of farms expands, sites of lower water quality are selected. This also affects the costs as it can cause a higher mortality and a lower growth rate. When all good sites are occupied, it may become worth considering onshore facilities, or any type of closed system. In this case water management cost is identified as such,

Table VII. Cost of vaccination

Assumptions	
	Smolts vaccinated at 25g
	1 l vaccinates 35kg fish
	Vaccine retails at £65.l^{-1}
	396 smolts yield 1t salmon at three market sizes: (1.5kg, 0.2; 2.5kg, 0.3; 3.5kg, 0.5)
Therefore	
	at FGV £1700.t^{-1} (trout), vaccine costs 1.0%
	at FGV £3000.t^{-1} (salmon), vaccine costs 0.6%

Table VIII. Cost of disease monitoring

Assumptions

one laboratory screening event costs £200

18 screening sessions per annum require £3600

All fish sampled are saleable, therefore zero cost

Size of decision FGV Unit t	£1700.t^{-1} (trout) £	£3000.t^{-1} (salmon) £
10	21.0	12.0
50	4.8	2.4
100	2.4	1.2

specifically with the energy cost. But the balance may be in favour of the water quality control to obtain the optimum rearing conditions.

A second question suggests that the actual move in salmon industry is more toward vertical integration, from the hatchery to the processing and marketing, than increase of plant size. With the reduction of margin, due to the rapid increase of the production, the farms obviously try to integrate better added value opportunities, which are in marketing and processing. The question is "what are the conditions (size, location, ...) for these farms to succeed in the competition with the specialized industry?". The trend is too dynamic to give an answer today.

Table IX. Cost of antibiotic treatment

Assumptions

One course treatment per tonne costs:

Oxolinic acid	(0.1kg)	£10.00
Trimethoprim	(0.21kg)	£ 8.60
Oxytetracycline	(0.75kg)	£27.00

Average stock receives three treatments per season.

At FGV	$£1700.t^{-1}$ (trout) %	$£3000.t^{-1}$ (salmon) %
Oxolinic acid	1.8	1.0
Trimethoprim	1.5	0.9
Oxytetracycline	4.8	2.7

Can we consider that small and large-scale plants can be viable simultaneously? As explained by S. Shaw small farms must at least reach a size where economies of scale are not too far from those of large-scale plants. Thus very small units have little chance to survive. But the difference in size can be very big, and economies of scale still comparable. The fact is that small or middle-scale units do not operate according to the same constraints. In an industrial logic, big farms must sell large quantities and may accept lower prices than a small farm selling its products on the local market.

References

Björndal T. 1987. Industrial structure and costs of production in the Norwegian aquaculture industry. Perspectiva de la Salmonicultura en Chile. Fundación Chile.

Shaw S. 1988. The economics of Scottish salmon farming. Proceedings of OECD Extended Meeting on Aquaculture, Paris.

Silbertson A. 1972. Economics of scale in theory and practice. Economic Journal 82 (suppl.).