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9. ABSTRACT

The commercial aquaculture or fish farm shows great promise as a source of low cost, high quality protein. However, as few reliable data on costs and returns to the industry exist, before investment decisions are made, certain critical factors such as water quality, species selection, and climatological conditions must be evaluated. Cultural conditions affecting market acceptance must be considered, and much more definitive work on the economics of aquaculture and its development potential in less-developed countries needs to be done. Toward these ends, pre-investment surveys of the economic, climatological, cultural, and biological constraints present in the field should be conducted. At least two commercial fish farms should be set up as joint projects between Asian and American universities for instruction, research, and extension. Technical assistance is needed to develop appropriate marketing and credit institutions and internal structures for the programs. Finally, a handbook for development workers, with a checklist of such items as details of pond and raft construction, economic criteria, etc., should be commissioned.

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FACTORS AFFECTING INVESTMENT DECISIONS IN AQUACULTURAL PROJECTS IN THE DEVELOPING WORLD, WITH PARTICULAR REFERENCE TO SOUTHEAST ASIA

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TABLE OF CONTENTS

SUMMARY AND RECOMMENDATIONS

I. SUMMARY

A. The commercial fish farm shows great promise as a source of low cost, high quality protein. However, little reliable data exists on costs and returns to firms in this industry, even in the United States. To extrapolate the available figures to indicate profit potential in underdeveloped countries would be unwise, but the available evidence suggests, as a first approximation, that the fish farm is definitely a paying proposition provided sufficient technical skills are possessed by or available to the operator of the facility.

B. Before an investment decision is finalized, certain critical factors involved with water quality, species selection, and climatological conditions, among other technical considerations, must be evaluated.

C. In addition to the technical factors, cultural conditions which influence market acceptance must be considered.

D. While the biological and engineering research necessary for the development of commercial aquaculture seems to be proceeding as well as might be expected, much more definitive work on the economics of aquaculture and its development potential in underdeveloped countries needs to be done. This need not be very esoteric research; simple cost and earnings data covering a fair range of conditions would go a long way in helping private entrepeneurs, government agencies, and international organizations make firm investment decisions.

II. RECOMMENDATIONS

A. As a basis for decision-making, competent professionals should conduct pre-investment surveys of the economic, climatological, cultural and biological constraints present in the field.

B. At least two commercial fish farms should be set up as joint projects between Asian and American universities, the facilities to be used for instruction, research and extension. Auburn and a number of other U. S. universities are involved in the biological aspects of aquaculture. It must be stressed, however, that the greatest need at the present time is for more understanding of the economics of aquaculture, and whatever universities are involved should be willing and able to apply economic analysis to all phases of the operation.

C. There is considerable need to supply technical assistance to develop appropriate marketing and credit institutions to meet the needs of this industry, and to enable host governments to develop sufficient in-house extension capabilities so that the maximum benefit can be derived from the program.

D. A handbook for development workers, containing a checklist of important factors, details of pond and raft construction, economic criteria, and similar topics should be commissioned.

II. FACTORS AFFECTING INVESTMENT DECISIONS IN AQUACULTURAL PROJECTS IN THE DEVELOPING WORLD, WITH PARTICULAR REFERENCE TO SOUTHEAST ASIA

Ryther and Bardach [1] define aquaculture as "the rearing of aquatic organisms under controlled conditions using the techniques of agriculture and animal husbandry". Since there are many risks and uncertainties involved in the aquacultural enterprise, the species which have been most often cultivated are those for which a ready market - generally a luxury market - exists. The fact that a particular species is considered a luxury is a function mainly of its price. While the price of any commodity is relatively high, efforts can be made to produce it more cheaply and thus to make higher profits on its production. In a competitive situation, this will cause more and more of the commodity to be produced, until the price falls and it is no longer a luxury. This is exactly what happened in the development of the U. S. broiler industry, and in the absence of artificial constraints, exactly what is beginning to happen in the catfish industry and what will probably eventually be the case for such species as shrimp and lobster.

In attempting to make an investment decision on an aquacultural enterprise, many considerations must be borne in mind. Among these are such things as the price of suitable land and the alternative uses to which it can be put.

By suitable land, we mean not only fairly level, cleared areas, but also land situated in a climatological region such that large fluctuations in water temperature, dissolved oxygen, sedimentation, and nutrient concentrations are not likely to occur during the year, or should at least occur only during a relatively short and predictable annual interval. A further requirement, obviously, is that the ground be capable of holding water in a pond, and that the soil

[1] The Status and Potential of Aquaculture, Vol. II.

substrate be of a type which contains no toxic or growth-inhibiting compounds. This last consideration sounds more important than it really is, as such soils are relatively scarce. More important, however, is control over the quality of the water supply, especially if hard pesticides are in use in the area.

Another major decision is the species to be raised:

1) will be a herbivore or carnivore?
2) does it require a narrow range of temperature, salinity, oxygen, and food conditions (implying a greater penalty for managerial and technical slip-ups than a hardier, though perhaps less valuable species)?
3) does it already enjoy a healthy local, regional, or national demand?
4) is the facility intended to produce cheap protein for the national market, or is the goal a high-surplus producing export commodity in order to earn foreign exchange?[2/]
5) is it particularly vulnerable to disease or predation at some stage in its life cycle? and
6) whether a uniform, low cost food supply is necessary, and if so, is it available to the fish?

Also to be pondered are questions about the availability and price of labor both for the construction of the ponds and also for their continuing maintenance and the care and harvesting of the crop; whether expensive imported pumps and aerators are necessary; whether persistent pesticides are in use in the surrounding zone (aside from building up

[2/] It is by no means self-evident that a locally consumed fish crop would be the more rational goal of national policy. It is at least conceivable that the profit generated by a high priced export commodity, such as shrimp, might be great enough to enable a nation to buy more equivalent protein (wheat or soybeans for example) on the world market than it could raise in its fish ponds in the first place.

in the flesh, rather low aqueous concentrations - about 3-4 ppm - can kill the fingerlings of many species outright); whether good sources of agricultural credit and technical assistance are available; whether the requisite management skills already exist in the population or must be trained from scratch; and so on. Naturally, similar questions must be asked with regard to possible development of <u>any other</u> technically advanced portion of the agricultural sector in an underdeveloped country. Some clearly defined goals are, thus, indispensable to the investment decision.

<u>Constraints</u>

Many of the above mentioned factors should be thought of as constraints upon the system. Other constraints are:

1) the water supply
2) the stocking density (which affects both the yield and the losses from disease, parasites, and predation)
3) property rights (especially if the culture operation is carried out in bays, estuaries, or other normally public areas)
4) industrial and agricultural pollution and the means for settling claims arising from such pollution
5) proximity to markets
6) processing and transportation costs
7) the price of competing commodities
8) the current state of the biological art

A commercial fish culture industry is not going to spring up overnight due to the introduction of one or two aquaculture projects. It cannot categorically be stated, at this point, that a commercial fish culture operation would be a better overall investment in an underdeveloped country than a poultry or hog production facility, though the evidence now available seems to suggest that substantial, though not unlimited, savings can be achieved over current production costs. [3] However, low costs of production do not by themselves guarantee a healthy industry, nor even a low market price. It is cultural conditions, climatological conditions, and geographic conditions, in addition to production costs which will determine the relative prices of such food in any country. These of course must be taken into account in the investment decision.

A hog farm in an Islamic country, for example, might have fantastic potential for producing meat. However, the market, as influenced by cultural conditions probably would not allow the profitable operation of such an enterprise. Thus, while many areas of Latin America have great potential yields in aquaculture, a successful aquaculture program would not only have to raise fish, but also raise the demand for fish within the area, unless intended for export. On the other hand, in an area such as South Asia, where the people already consume large amounts of seafood, it is felt that the market potential for commercial capital intensive and highly productive aquaculture is much greater than in any other underdeveloped area. In areas such as Latin America, and parts of Africa as mentioned above, the wisest course would be the introduction of simpler forms of aquaculture, so as to entail less risk and at the same time develop the managerial and technical skills which will be necessary for the more productive intensive pond or raceway culture.

It seems that the evolution of fish culture in underdeveloped countries can come about in three stages. First, would be the concurrent raising of fish and rice in a

[3] See, for example, Greenfield (1969;1970); Miller and Nash (1969).

single rice paddy or in a mangrove swamp.[4/] Second, and slightly more specialized, requiring slightly greater investment would be raft culture of mussels or oysters in fairly well protected coastal waters. And third, the commercial salt or fresh water fish farm. It should be recognized at once, however, that the first two forms of aquaculture are of a type which do not require extremely sophisticated management skills nor high capital investments, nor do they require large amounts of labor. The third variety, however, can be efficiently carried on only with rather large capital requirements, a high degree of managerial skills, and a not inconsiderable background of tecnological and biological supportive services.

This third stage is qualitatively quite different from the other two. The first two stages involve naturally reproduced juveniles which are essentially on their own, but are kept in physical contact with an area under the control of an operator. The organisms generally ingest whatever becomes available to them as a result of natural actions. On the fish farm, however: 1) selection of brood stock for genetic characteristics is possible; 2) organisms are reared through all stages of the life cycle (although fingerling production may be a separate commercial operation); and 3) the organisms' food is generally supplied almost entirely by the operator. These differences, while creating a situation in which greater production and high profits can be realized, also multiply the entrepeneurial risks involved.

[4/] This is a stage which already has been passed in many South Asian countries. It is, furthermore, a stage which is rapidly becoming incompatible with agriculture for two reasons. First, pesticides are being used in increasing quantities in these areas to protect the rice crop and second, the growing use of high-yield rice strains has made possible a considerable shortening of the growing period. Since the paddies are thus drained earlier, the organisms, even in the absence of pesticides, would not have sufficient time to grow to marketable size.

To be sure, the same is true of the broiler industry, where one could also distinguish three (although not analogous) levels of production. The first would be a chicken coop found behind the house, raising a few chickens for family use. The second level would be the farmer who raises a fair amount of chickens for market, but is not using production line methods, which would be the third or most capital-intensive phase of production.

It must be pointed out that certain species, particularly the carps, are extremely hardy fish which can grow under a wide range of conditions; this means that the penalty for managerial or technical mistakes - mistakes which are bound to be made in any developing industry - is not as great as it might be with a species such as trout or shrimp. And if the carp species already enjoys widespread market acceptance, as this writer understands, throughout much of Asia, then two prime uncertainty factors can be minimized immediately.

There is a substanital opportunity for the culture of various additional species of fish which are native to fairly extensive bio-geographic areas of the world but which have not been cultured because too little attention has been paid to their biology. These species would, of course, enjoy good market acceptance in the regions to which they are indigenous. Uniquely adapted to their regions, resistant to local diseases and predators, these species contain genetic material which could probably be manipulated by breeding techniques to produce very high-yielding varieties. Such is not the case with the carps, which appear to have reached a plateau in their productive capacities as a result of many centuries of selective breeding.

Given all of the foregoing, it is felt that while commerical aquaculture has tremendous potential, particularly in an area such as South Asia, the utter lack of economic data necessary to evaluate the profit potential of such an undertaking in an underdeveloped country at the present time would make it a highly speculative venture for a private entrepeneur. Recognizing that failures often have reinforced resistance to improved methods - even though these failures have come about many times due to purely extraneous circumstances - an agency or government wishing to invest in such a project would best be advised to finance the undertaking under the joint auspices of the development agency, a local university, and an American university. This would provide the necessary technical backstop, plus a relatively risk-free atmosphere in which to conduct training and research. Such a facility should be planned so as to shift gradually from a complete intensive fish culture operation to one with greater emphasis on fingerling production, as an industry grows up around it.

A further need is to have a handbook, or at least a pamphlet, written in non-technical language so that development workers can be made aware of the potential in this field, while providing them with a checklist of necessary conditions - biological, physical, economic, and cultural - which will enable them to carry out at least a preliminary site evaluation.

III. AN EXAMINATION OF THE COST OF PRODUCTION OF CHANNEL CATFISH UNDER INTENSIVE CULTURE IN THE UNITED STATES

In an attempt to indicate the economic returns possible in the fish-farming business in the United States, we will examine closely the results obtained in a Georgia experiment in 1969, described in a paper entitled "Hypothetical Costs for Earthen Raceway Culture of Channel Catfish", by E. E. Brown and J. Chesness, presented at the Conference on High Density Fish Culture at the Skidaway Institute of Oceanography, Skidaway Island, Savannah, Georgia.

This experiment was set up to ascertain both the production possibilities and the cost structure associated with varying stocking densities. Densities of 2, 4, and 6 fish per cubic food were observed, while densities of one-half and one fish per cubic food were calculated by extrapolating the trend of feed conversion rates (2.07:1 @ 2 fish/cu.ft., 2.31:1 @4, and 2.45:1 @ 6), back to the lower points. This writer feels that such an extrapolation is risky under the best of circumstances. With only three other stocking rates observed on which to base this extrapolation, it is felt that not much faith can be placed in the figures for .5 and 1.0 fish per cubic foot, except perhaps, as an educated guess. However, since the authors present these calculations along with the other data with the caveat that <u>all</u> the results should be regarded as hypothetical until testing on a larger scale, over a longer period, under true field conditions can be carried out, it is felt that the data presented give us a useful first approximation to the production function of a commercial fish farm.

Essentially, the experiment uses two inputs, fingerlings and feed, to produce channel catfish. Other fixed equipment and physical inputs are necessary as well, of course, but are held constant. As the fingerling stocking rate was varied, so was the amount of feed given to the fish. Thus, if we think of the fingerlings, and the feed and chmicals and harvesting labor they require together as our single variable input used in producing the output of catfish, we may be able to come up with some illuminating figures.

Table 1, from their paper, is reproduced on the following page. It shows that from the possibilities tested, the stocking rate of 2 fish per cubic foot gives the highest gross return to management and land. It also suggests that extremely high concentrations of fingerlings in the pond (above 6/cu.ft.) may indeed approximate the returns available at the lower rate[1/]. This writer, however, feels that the returns figures are overstated by not showing an "interest on working capital" item in the "annual costs" schedule. This is especially significant in the case of fingerling cost at the high stocking densities, since the money presumably is spent at the start of the growing season. This expense, plus the money spent on feed throughout the season, if discounted at a "risky business" internal rate of 20%, would nearly wipe out the returns to management and land altogether. So, we may fairly categorically state that the true returns to land and management reach a peak somewhere in the vicinity of 2 fish/cu.ft., and then fall off sharply.

To better reflect the foregoing, the cost calculations which will be made will include an "interest on working capital" term, covering the items of fingerlings, feed, power, maintenance, chemicals, daily labor, and miscellaneous (harvesting cost is not considered since the crop is sold when harvested, presumably for cash). The yearly average balance of all expenses but fingerlings is taken to be one-half of the total. Fingerlings, since they are purchased only once at the very beginning of the growing season, are taken at full value. Both are discounted at 20%.

[1/] This is wholly apart from the greater risk of predation, parasitism, disease, and toxicity inherent in the higher stocking rates.

Table 1. Hypothetical costs for 25 earthen raceway segments using different stocking rates

	Stocking rate/cubic foot				
Initial costs	.5	1	2	4	6
Construction-pond (3 acres)	3000	3000	3000	3000	3000
Land: 8 acres @ $150/acre	1200	1200	1200	1200	1200
Construction-25 seg.@$400	10000	10000	10000	10000	10000
Service Building	500	500	500	500	500
Pumps (30ft.lift) 2 @$500	1000	1000	1000	1000	1000
Pipe	1500	1500	1500	1500	1500
Handling Equipment	200	200	200	200	200
Total (inital costs) $	17800	17800	17800	17800	17800
Annual costs					
Fingerlings[1] @ 5¢	2825	5626	11250	22500	33750
Feed[2] @ $120/ton	5900	11000	19350	26675	40650
Power cost[3]	120	240	240	240	240
Maintenance	150	150	150	150	150
Depreciation[4]	275	275	275	275	275
Labor, daily[5]	2100	2100	2100	2100	2100
Harvesting[6]	300	350	450	525	600
Chemicals	125	190	250	375	500
Interest on investment (8%)	1400	1400	1400	1400	1400
Miscellaneous[7]	100	100	100	100	100
Total (annual costs) $	13295	21455	35565	54565	79765
Total Pounds of Production	49075	89450	153625	193275	276550
Cost per pound of production	27.0	24.0	23.2	28.1	28.8
Gross Returns to Land, Management @ selling price of 35¢ $	3877	9840	18128	13336	17146

Source: "Hyphothetical Costs for Earthen Raceway Culture of Channel Catfish", by E. Evan Brown and Jerry L. Chesness; Skidaway Institute of Oceanography, Savannah, Georgia.

Footnotes to Table 1:

1. Each segment has 4500 cubic feet of water with stocking rates of .5, 1, 2, 4, and 6 fish per cu. ft.; stocking rates per segment are 2250, 4500, 9000, 18000, and 27000 fingerlings. 25 segments are in each raceway area.
2. Feed conversion rates are 2.0, 2.05, 2.1, 2.3, and 2.45 respectively. Average weights of fish at the end of 26 weeks are 396, 361, 310, 195, and 186 grams respectively from lower to higher stocking rates. Total pounds of fish produced per segment are 1963, 3578, 6146, 7731 and 11062 pounds respectively.
3. Assuming one pump working for 7 months, one 12 months for lower stocking rate, and 2 pumps for 12 months at all other stocking rates.
4. Depreciation of service building, handling equipment, pipe, pumps.
5. Seven months @ $300/month.
6. Harvesting labor is affected by stocking rates. Need four men at $1.25 hourly. From 2 hours to 4 hours per segment depending on stocking rates.
7. Includes telephone, advertising, taxes, etc.

The reason for the difference between this rate and the 8% on invested capital is due to the fact that the 8% is probably quite near the cost of capital to the operator in the financing of land and improvements only. It is extremely doubtful that, in an infant industry such as this, he could borrow the funds with which to buy fingerlings at less than usurious rates unless he was the beneficiary of one or another government subsidy programs.

Thus, the corrected values of the gross returns to land and management are summarized in this table:

Stocking density	.5	1	2	4	6
Gross returns	2450	7350	13735	5950	5904

Taking all other figures at their face value, however, we can, by means of a few simple computations, derive data on the marginal and average costs, and marginal physical productivity as a function of the amount of fish stocked per cubic foot. These figures can be seen in Table 2, on the following page.

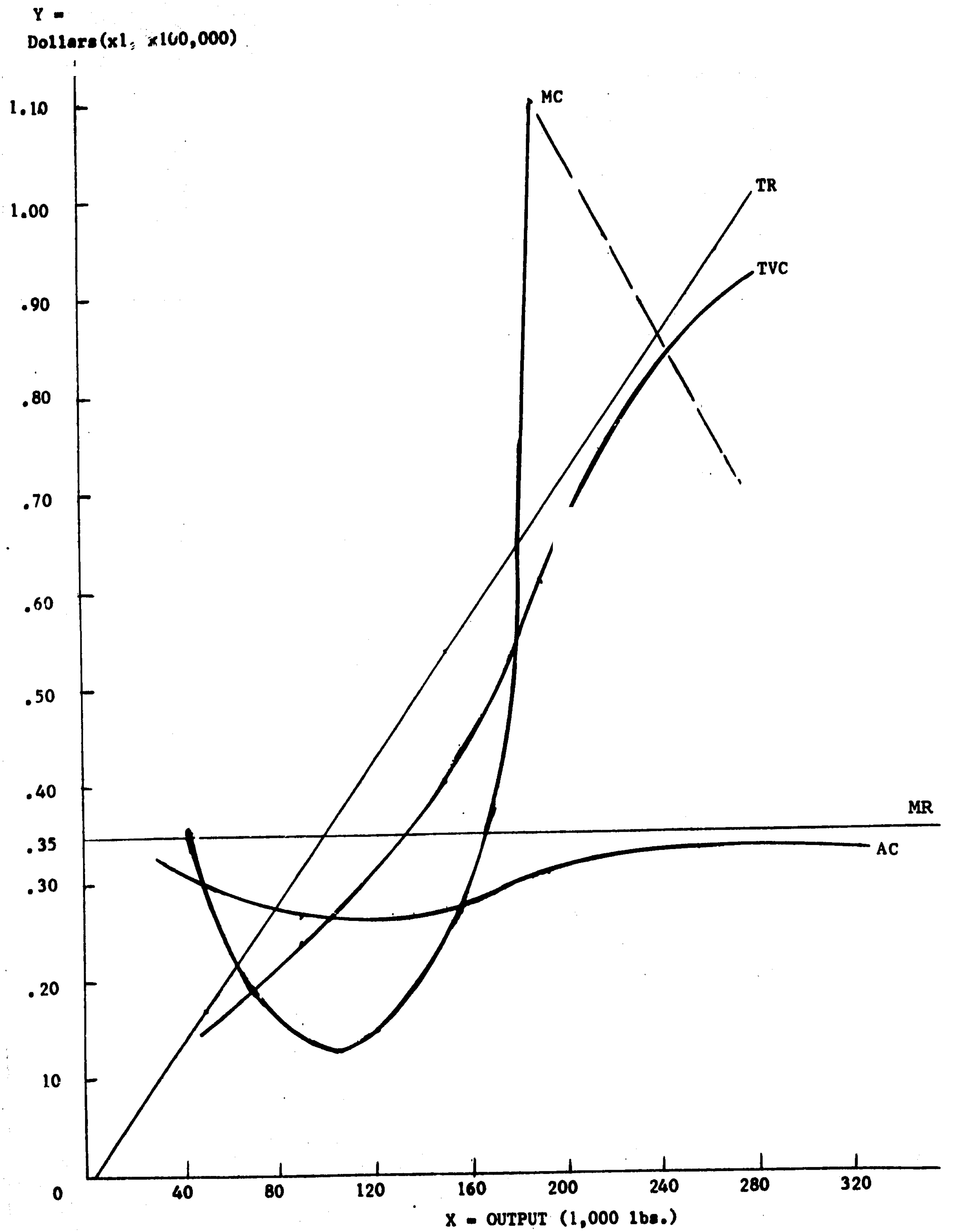
Graphing these functions as a function of output (X) and input of fingerlings (Z) shows us a number of interesting relationships.

In the first graph, we notice that marginal cost rises steeply between output levels of 150,000 to 190,000 pounds, and then begins to fall again. Marginal cost is equal to marginal revenue, according to the graph, at an output of about 158,000 pounds of catfish. On the second graph, we see that, as a function of stocking density, marginal cost equals marginal revenue at about 2.12 fish per cu. ft. This, then, is the most profitable point of production. Referring to the total cost and total revenue curves, we see that at that point TC=42,600 while TR=56,500, giving a total profit (earlier referred to as gross return to management and labor)

Table 2. Derived Cost and Productivity

Stocking denstiy (Z)	TPP (X)	MPP	APP	TR	MR	TVC	MC	AVC
	LBS.	LBS.	LBS.	($)	($)	($)	(¢)	(¢)
.5	49,075	49,075	98,150	17,176	.35	14,710	30.0	30.0
1	89,450	80,750	89,450	31,308	.35	23,958	11.5	26.8
2	153,625	64,175	76,813	53,769	.35	40,034	25.1	26.1
4	193,275	19,825	48,319	67,646	.35	61,696	109.3	31.9
6	276,550	41,638	46,092	96,793	.35	90,889	70.1	32.9

TPP = TOTAL PHYSICAL PRODUCT
MPP = MARGINAL " " $\left(\frac{dx}{dz}\right)$
APP = AVERAGE " " $\left(\frac{x}{z}\right)$
TR = TOTAL REVENUE
MR = MARGINAL "
TVC = TOTAL VARIABLE COST
MC = MARGINAL COST
AVC = AVERAGE VARIABLE COST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1.00
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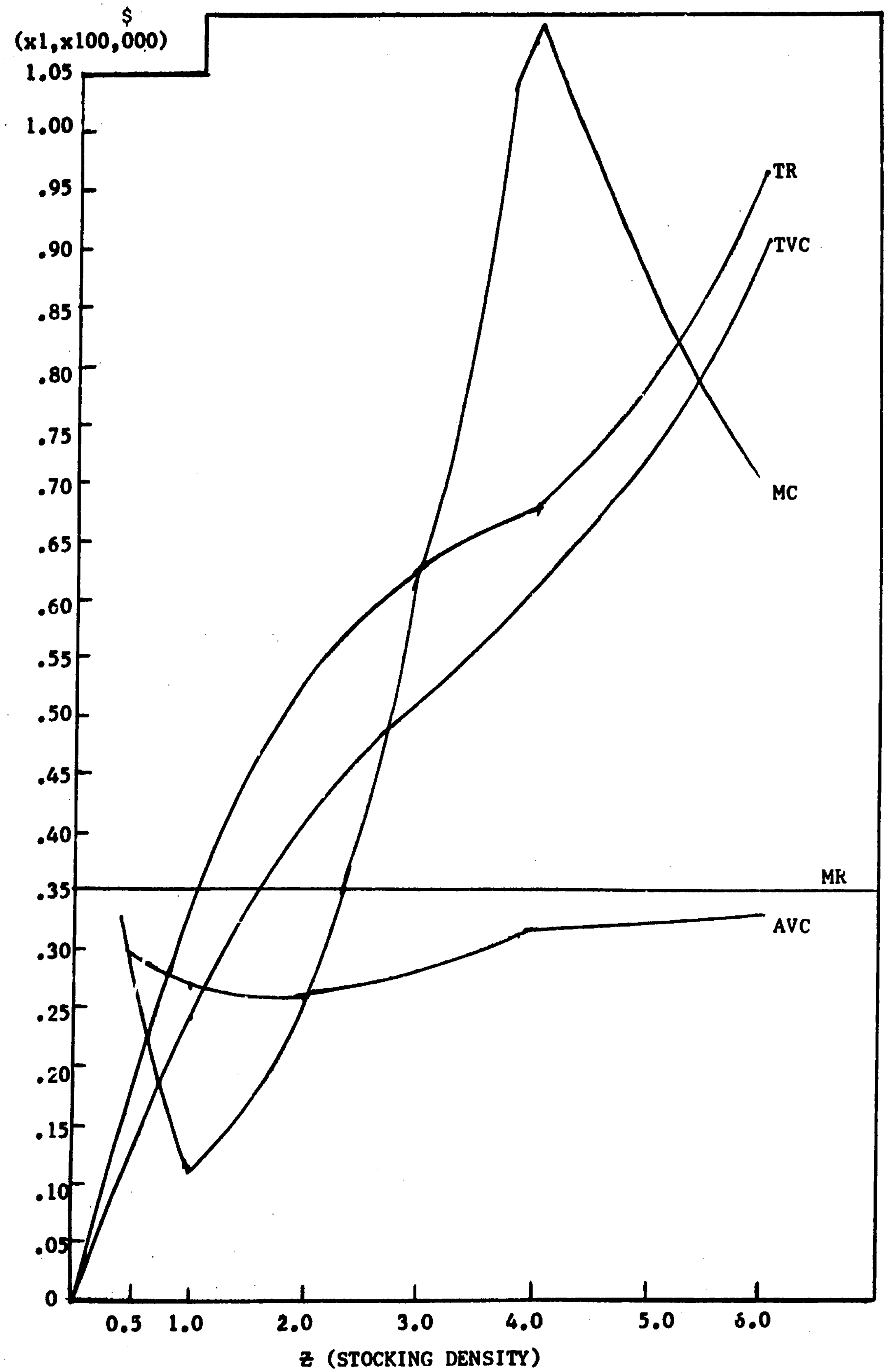
TR
TVC
MR
AC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6.0
z (STOCKING DENSITY)

of about $13,900 which is much as we would expect. As a practical matter, one would probably not stock fingerlings right up to this marginal point, but would be better advised to stock only 2.0 fish/cu.ft., since the curve rises so sharply after that point. That is to say, the penalty for erring on the lowside is less than that for erring on the highside.

A least-squares regression analysis could be performed on this data to come up with an actual production function, expressed either in terms of a single combined input variable (fingerlings, feed, chemicals, and harvest labor) or as a multiple input product, obtaining coefficients for each. It is felt that this data, however, is a bit too tentative to merit more sophisticated analysis, and at any rater there are not enough observations to make the results statistically valid.

Returning to the graphical presentation, we notice one perplexing situation with regard to this data; marginal cost turns down again at high stocking density. In this case, it could be that for some reason the fish waste less food when packed in at 6/cu.ft. than they do at 4/cu.ft. This indeed is the only explanation other than experimental error which occurs to this writer. Possibly this could be corrected by a modification of the feeding process. If so, we would most likely see a marginal cost curve which did not rise nearly so steeply between 2 and 4 fish/cu.ft., which would imply that the optimum stocking density might be somewhat higher than the 2.12/cu.ft. arrived at with the available data.

From the foregoing, we can thus conclude that there appears to be great profit potential in intensive aquaculture. Gross returns to management and land have been shown to be on the order of $2000/acre before taxes. The productive potential of intensive aquaculture would seem to be tremendous.

While it is hazardous to generalize from a domestic industry to a similar one in a developing country, all the evidence points to a bright future for aquaculture in the developing world. Aquaculture is most definitely <u>not</u> the answer to the world's food shortage, however, since at present only relatively high priced species are cultured. Aquaculture could, however, go a long way toward alleviating the problem, and should before long reach the level of technological sophistication which has been achieved by the broiler industry in many parts of both the developed and developing world.

APPENDIX A

The following table is taken from "The Status and Potential for Aquaculture" by Ryther and Bardach (1969). It shows a sampling of aquacultural operations of varying degrees of sophistication around the world, and attempts to give some idea of the gross returns per acre of "cultivated" water.

Summary of Aquacultural Yields with Ascending Intensity of Culture Methods
(Units in Fresh Weight, Shells of Molluscs Excluded)

Location	Species	kg/ha/yr	t/acre/yr	Local Wholesale value $US/acre
I. TRANSPLANTATION OF SPECIES:				
Denmark	plaice	no - data - available		
II. STOCKING OF HATCHERY - REARED JUVENILES:				
Great Britain	plaice, sole			
Japan	shrimp, crab, abalone, sea bream, puffer fish, Pacific salmon, others	Cost : Benefit 1:3 1/2 - 5 1/2, based on hatchery costs and return to commercial fishery.		
United States	lobster, Pacific salmon			
III. CULTIVATION OF STOCKED OR NATURAL POPULATIONS, NO FERTILIZATION OR FEEDING:				
United States	oysters (national avg.)	9	0.004	16
United States	oysters (best yields)	5,000	2.00	9,000
France	flat oyster (national avg.)	400	0.16	2,000
France	Portuguese oyster (national avg.)	935	0.37	1,500
Australia	oysters (national avg.)	150	0.06	170
	oysters (best yields)	540	2.20	6,250
*Japan (Inland Sea)	oysters	58,000	23.30	28,000
Malaya	cockles	12,500	5.00	800
France	mussels	2,500	1.00	750
Philippines	mussels	125,000	50.00	8,000
*Spain	mussels	300,000	120.00	20,000

Location	Species	kg/ha/yr	t/acre/yr	Local Wholesale value $US/acre
*Japan	Porphyra	7,500	3.00	3,000
*Japan	Undaria	47,500	19.00	850
Singapore (elsewhere in SE Asia)	shrimp	1,250	0.50	600

IV. STOCKING AND CULTIVATION: FERTILIZATION, NO FEEDING:

Location	Species	kg/ha/yr	t/acre/yr	Local Wholesale value $US/acre
Taiwan	milkfish	1,000	0.04	
Israel, SE Asia	carp (related sp.)	125-700	0.05-0.28	
Africa	Tilapia	400-1200	0.16-0.48	
Java (sewage streams)	carp	500,000-750,000	200-300	
Japan	Chlorella	325,000	130	none

V. STOCKING AND CULTIVATION: FERTILIZATION AND SUPPLEMENTAL FEEDING:

Location	Species	kg/ha/yr	t/acre/yr	Local Wholesale value $US/acre
United States	catfish	3,000	1.20	1,000
China, Hong Kong	carp (related sp.)	3,000	1.20	
Israel	carp, mullet	2,100	0.84	

VI. STOCKING AND CULTIVATION: RUNNING WATER, INTENSIVE FEEDING:

Location	Species	kg/ha/yr	t/acre/yr	Local Wholesale value $US/acre
United States	rainbow trout	>2,000,000 (170kg/liter/sec)	>800	(168 per c/sec)
Japan	carp	1,000,000-4,000,000 (ca 100 kg/liter/sec)	400-1,600	
Japan	shrimp	6,000	2.4	18,000

*Raft-culture calculations based on an area 25% covered by rafts. To obtain yields for area actually involved in production, multiply by four.

APPENDIX B

An examination of certain economic data relating to pond culture.

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SUMMARY OF INVESTMENT AND PRODUCTION ON SOME NORWEGIAN TROUT FARMS IN 1966 1/

Farm	Total Construction Cost in US Dollars 2/	Production Capacity (Maximum achieved) Lbs.	Cost in cents per pound of capacity	Ratio of cost achieved to capacity cost (%)	Notes of Favor
A	4,200	13,228 (6,614) a/	32 64	2.0	Sea water plants, concrete ponds, pump operation, buys stocking fish.
C	36,400	44,092 -	83 -	-	Fresh, brackish and salt water. Pump operation.
H	8,400	11,023 (5,512) a/	76 152	2.0	Combined plant. 3/ Concrete ponds on land. Pump operation in floating pond.
I	70,000	110,231 (44,092) a/	64 158	2.62	Combined plant. Concrete ponds. Freezing plant. Pump operation.
J	28,000	22,046 -	127 -	-	Combined plants. Pump operation.
Q	1,120	22,046 (22,046) b/	5 5	1.0	Combined plant. Pump operation. Buys gearling stocking Fish.
R	140,000	286,601 (132,277) a/	49 106	2.16	Combined plant. Fresh, brackish and salt water. Pump operation.
T	42,000	176,370 (15,432) a/	24 272	11.33	Combined plant. Fresh, brakishard salt water. Pump operations.
Z	5,600	44,092 (11,023) a/	13 51	3.92	Earthen ponds mostly. Small pump capacity.
Average	37.240	(11.023) a/	46		

Notes on Summary Table for Norwegian Trout Farms, 1966

1/ Source:

Leidlev Berge, Pondfish Farming in Norway, Survey of the Situation Today and an Evaluation of Some Profitability Factors. Papers on Fisheries Economics No. 5, Institute of Fisheries Economics, The Norwegian School of Economics and Business Administration, Bergen, Norway, 1968, 79 pp. In Norwegiano English Translation by U.S. Joint Publications Research Service for Bureau of Commercial Fisheries, November 1969, p. 36.

2/ Conversion Factor: one Norwegian Kroner = 0.14 U.S. Dollars in 1966.

a/ Achieved in 1965.

b/ Achieved in 1963.

3/ "Combined Plant" means farms that engage in entire production process. Includes stripping brood fish, hatching roe, rearing fry, stocking fish, panfish and food fish. Also included in this group are farms which buy eggs, fertilize and hatch them thereby avoiding brood fish maintenance.

The Norwegian data (Berge, 1968) indicate a construction cost per pound capacity of 5¢/lb - $1.27/lb. This range reflects the heterogeneity of Berge's sample.

It includes farms engaged solely in production and farms raising brood fish, etc.; some farms with freezing plants and some without freezing facilities. Furthermore, when idle capacity is taken into account, these ratios change greatly for some farms. If construction cost is computed per pound of actual (highest achieved) production, one obtains a range from 5¢/lb. to $2.72/lb. Thus, the degree of underutilized capacity has a very large effect on average productivity ratios.

Based on a sample of twenty-seven catfish farms in East Arkansas in 1968-69, Mullins (1969) indicates the following approximate per acre capital requirements for catfish farming.

Item	$	$/Acre
Levee construction (760 acres)	119,435	157
Stand & drain pipes (1,072 acres)	13,077	12
Road surfacing (655 acres)	2,850	4
Wells, pumps & motors (1,112 acres)	91,920	83
Holding tanks, supply, storage, etc.		25
Total: (applicable to open land)		281
Tree and/or stump clearing and land smoothing (291 acres)	15,062	52
Total: (applicable to wooded or stumpy land)		333

The preceding figure does not include the cost of land. Since land costs are highly variable with respect to location, etc., it is best added in to fit the circumstances. Assuming a yield of 1,500 lbs. catfish per acre per year, the preceding figure implies an investment of about 19¢/lb. - 22¢/lb., plus land costs. Also excluded are the costs of any special equipment required in carrying on the enterprise.

In another study, initial costs for a five acre catfish pond in Georgia, 1969.

	$/Acre
Pond construction (SCS estimate)	1,000
Land cost (marginal land assumed)	150
Drain pipe (cost data)	34
Service building (cost data) 500/acreage - $\frac{\$500}{5 \text{ ac.}}$ ≠	100
Boat cost (cost data) $\frac{\$140}{5 \text{ ac.}}$	28
Handling equipment (cost data)	40
Aerator cost (cost data) $\frac{\$250}{5 \text{ ac.}}$	50
	$ 1,352

1,500 lbs. catfish/acre/year = 90¢/lb. initial investment per lb.

Principal divergencies from Mullins:

Pond/levee construction $1,000 - $157 =	$843
Aerator	50
Handling equipment	40
Service building	100
	$1,033

÷ 1,500 = 68¢/lb
+23C/lb
91 - 93¢/lb.

APPENDIX C

A comparison of capital output ratios of agriculture and poultry.

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Comparison of Capital Output Ratios of Agriculture & Poultry

One of the great difficulties in such a comparison arises when one examines the connections between production of fish or poultry and supportive industries. In the U.S., it is the extreme sophistication of supportive industries in poultry which permits such efficient production. By supportive industries, we refer to such ones as grain production, feed handling and transport. For example, Zusman and Hoch (1965) found that for each dollar of capital invested in expansion of poultry (expressed as a ratio) per dollar of expanded product value, the following ratios held.

Capital Coefficient Matrix for California
1954 - base year

	2	4	11	12	15
2. Poultry and eggs	.1902	0	0	.0076	.0003
4. Food and food grain	.0059	.3328	.0320	0	.0004
11. Grain mill products	.0266	0	.0359	.0412	.0098
12. Meat and poultry processing	0	0	.0006	.0412	.0028
15. Misc. Agr. processing	0	0	.0034	.0007	.1272

Source: Pinhos Zusman and Irving Hoch, Resource and Capital Requirement Matrices for the California Economy, Giannini Foundation Research Report No. 284 (Aug. 1965).

Thus, a one dollar expansion in the output of the poultry and egg sector in California directly required about 19¢ of additional capital to be invested in the industry. In addition, this same dollar directly required small incremental investments in both the meat and poultry industry and the miscellaneous agricultural processing sector as well. Further, these direct requirements raise production in all the sectors involved, giving rise to indirect capital requirements in still other industries. Specifically, for every dollar's investment required in the meat and poultry industry, 4.12¢ investment is required in the grain mill products sector. These indirect requirements sometimes exceed the direct capital requirements.

More relevant than the actual magnitude of the preceding numbers is the interdependence which they imply. If one is to compare aquaculture efficiencies with poultry the requisite infrastructure must be somewhat comparable.

All of the foregoing in this section has been by way of saying that we must go pretty far afield to come up with a basis of comparison between the fish culture industry and the poultry industry even in this country. The hard economic data we need simply does not exist at the present time. This fact alone suggests that fish culture in underdeveloped countries might be a highly profitable undertaking.

It seems likely to us that a comparison of American poultry efficiency with aquacultural efficiencies should not be used as a guide for underdeveloped countries. A more relevant comparison might be aquaculture with native poultry.

The principal cost of either poultry or aquaculture (finned fishes) is feed. The transportation sector of many underdeveloped countries is very poor and transportation will be a significant component of food costs unless the distance is short. This suggests that the question of competition/substitution between poultry/aquaculture must be related to feed costs, geography, and transportation costs. Broadly, we would characterize three zones as follows:

Zone I: Adequate (or potentially so) supplies of grains for poultry production. Poor or inadequate water supplies for aquaculture.

Zone II: Adequate water supply, adequate supply of commercial fisheries by-products for feeding aquaculture. Adequate grain supplies for poultry.

Zone III: Similar to Zone II except grain supplies are poor. Only in the case of Zone II is there real competition between the two.

Superimposed on the preceding three zones is the question of market proximity. It may be assumed that movement of product to market is via a poor marketing/transportation network. This tends to restrict aquaculture to areas relatively close to population centers, unless the product is dried, smoked, or otherwise preserved. This constraint, however, is subsumed by the larger question of market acceptance, that is, if a market already exists for the fish in some form or another, transportation will not be a very large problem, except insofar as transportation costs affect the relative price levels of pond-raised fish and competing commodities.

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