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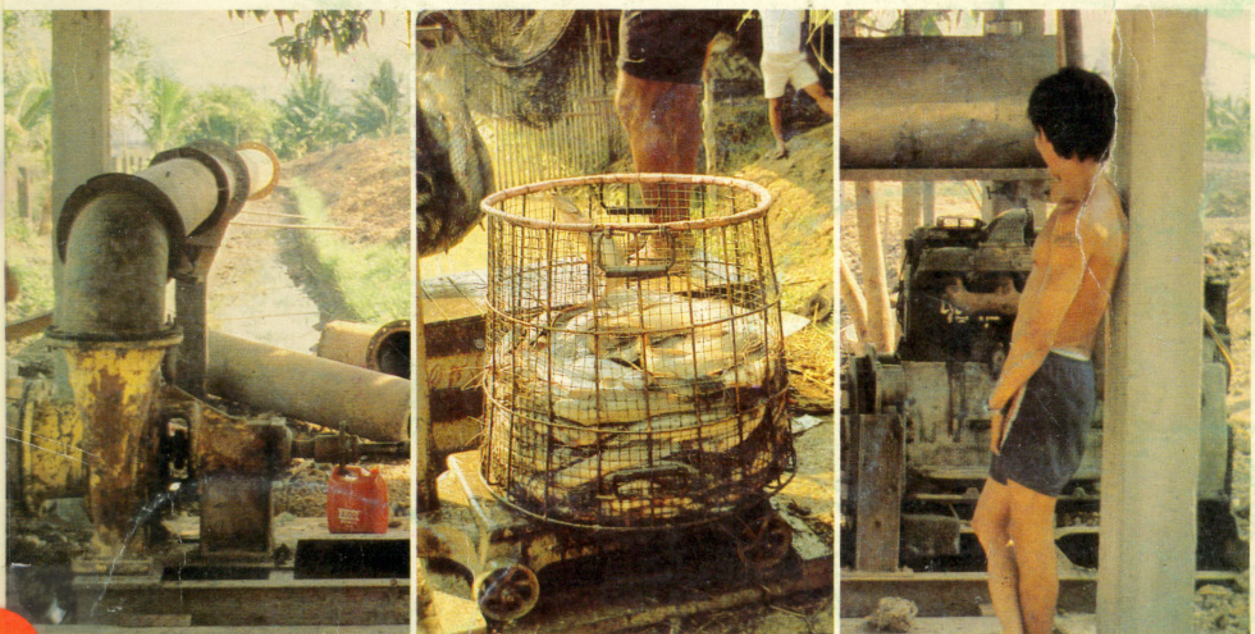

KASETSART UNIVERSITY RESEARCH AND DEVELOPMENT INSTITUTE
INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT

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Cover: Some inputs to catfish farming–water pumping and labor– and the output, *Clarias batrachus*, being weighed.

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Preface

In recent years, the growing demand for fishery products, coupled with declining yields from capture fisheries, has stimulated inland fish culture. In Thailand, the most commonly cultured fish species are tilapia, carps, snakehead and catfish. Among these, the culture of catfish *(Clarias batrachus)* has been quite popular because of its short culture cycle and high rate of return.

However, during 1974-76 there was a dramatic fall in the number of farms and pond area due to the incidence of disease affecting catfish and the rising price of inputs, especially trashfish which is commonly used as feed. Rising production costs, as well as high mortality rates, have resulted in losses to catfish farmers. This decline affected not only the producers but had also a pronounced effect on the consumer as, by 1977, catfish prices began to rise sharply.

Theoretically, the increase in price caused by the excess demand should have induced a rise in production and a corresponding increase in supply. However, the recovery of the catfish farming industry has not been proceeding at the rate one would have expected, given the high and rising fish prices. Under these circumstances, an economic study of catfish production was undertaken by the Department of Agricultural Economics of Kasetsart University, with the support of ICLARM, to investigate the economics of catfish production in the main catfish culturing areas of Suphan Buri and Nakhon Nayok. This technical report, jointly published by the Kasetsart University Research and Development Institute (KURDI) and ICLARM presents the results of this enquiry.

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Bangkok, July 1982

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Abstract

Panayotou, T., S. Wattanutchariya, S. Isvilanonda and R. Tokrisna. 1982. The economics of catfish farming in central Thailand. ICLARM Technical Reports 4, 60 p. Kasetsart University Research and Development Institute, Bangkok, Thailand and International Center for Living Aquatic Resources Management, Manila, Philippines.

A recall survey of 41 catfish farms in the Central Plain of Thailand during 1979 was undertaken to ascertain why production has been falling since 1974, despite high and rising market prices for catfish. The survey results showed that many catfish farmers have switched to the culture of other species or to the cultivation of rice and other crops; some even left the area to take other occupations. The main reasons given in the interviews were high fish mortality due to disease and escalating feed (trashfish) prices. Yet, some of the farms that stayed in business made considerable profit, due to superior managerial ability of the owners, access to low-cost credit and diversification of farming to spread risk.

A Cobb-Douglas production function was employed to explain variation in output observed from farm to farm. Eighty percent of the variation in output could be explained by the following explanatory variables (inputs): stocking rate, feeding rates of trashfish and broken rice, fuel for pumping water, medication of fish, size of farm, and experience of the operator. Profits could be increased by reducing the average catfish stocking rates and quantity of trashfish used as feed, and by increasing the use of broken rice and fuel for the purpose of changing pond water.

Introduction

BACKGROUND

In contrast to the remarkable Thai fisheries development of the 1960s, recent years have witnessed a reduction in the growth of fish supplies as a result of overfishing, water pollution and rising fuel prices. A further dramatic decline in marine fish production is expected as a result of the declaration of 200-mile exclusive economic zones by neighboring countries. The demand for fish, on the other hand, has been rising rapidly as a result of increases in population, in income per capita, in exports and in the prices of alternative sources of animal protein. With supply lagging and demand rising, the prices of fishery products have been increasing rapidly with adverse effects on the welfare of low-income people whose protein intake is derived mainly from fish, the traditionally lowest-priced source of animal protein. Moreover, Thailand, facing mounting balance-of-trade deficits, can ill afford a curtailment of its fishery exports.

Among the proposed solutions to the problem of lagging supply and rising fish prices in Thailand have been: (i) management of marine and freshwater fisheries; (ii) fishing ventures with neighboring countries; and (iii) promotion of fish culture. Not only is there a limit to the amount of fish obtainable from natural sources on a sustained-yield basis, but also enforcement difficulties frustrate the management schemes required for its attainment. Joint fishing ventures, however successful, provide only a partial and at any rate, temporary solution to the lagging supply of fishery products. In contrast, fish culture may provide a long-term alternative to capture fisheries in a country with abundant waters, fish farming experience and existing markets.

Fish farming in inland waters has long been practiced in Thailand. In earlier times, farmers were encouraged to grow fish in paddy fields with emphasis on rearing herbivorous or omnivorous species such as tilapia, carps and sepat-siam *(Trichogaster pectoralis)*. Commercial-scale aquaculture is a rather recent development, spearheaded by recent advances in fish-culture technology and by the increase in freshwater fish prices following the decline of supplies from natural sources. The species raised include catfish (*Clarias* spp.), striped catfish *(Pangasius sutchi)*, mudfish *(Channa striata)*, sepat-siam, carps, tilapia and giant prawn *(Macrobrachium rosenbergii)*.

The culture of catfish has been particularly popular because of its short culture cycle, ability to survive a wide range of water conditions and high market price. Traditionally, catfish were obtained from natural sources such as paddy fields during harvest and canals but supply from these sources was adversely affected by the use of agricultural pesticides and the filling up of canals for road construction. This development, coupled with the increase in demand has encouraged the culture of catfish in ponds, but after a brief boom in the late 1960s and early 1970s, the culture of catfish declined and its capture from natural sources has been partially revived (see Appendix Table 1).

A study of the economics of catfish culture would provide useful information for the solution of problems faced by catfish farmers.

DECLINE IN CATFISH PRODUCTION

As a result of the high profitability of catfish farming and the absence of barriers to entry, the number of catfish farms in Suphan Buri Province, the largest catfish-farming area of the country, increased rapidly from 45 farms (54 ponds) with an area of about 16,506 m^2 in 1967 to 468 farms (1,123 ponds) with an area of about 495,646 m^2 in 1973 (Kloke and Potaros 1975). Three years later, however, according to the Department of Fisheries, there were only 76 farms (288 ponds) with an area of 343,788 m^2, due to the exit of a large number of small farms (see Appendix Table 2) as a result of losses caused by spread of catfish diseases and the rising prices of inputs, especially that of trashfish, the major ingredient of feed, at an average annual rate of 40% during 1973-80. The rapid rise in the cost of production and the slow increase in the price of catfish (at an average annual rate of 24% during 1973-80) brought losses to many farmers. Tugsinavisuitti and Onchan (1979) found that catfish farmers incurred an average loss of about 21,965 baht per farm in 1975. The peak production of catfish of 40,262 mt, valued at 5,798 million baht in 1973 dropped to 19,714 mt, valued at 315.4 million baht, in 1976 (Appendix Table 1), a change that affected not only the producers but had a pronounced effect on the consumers as well. As a result of the drop in supply and the continued rise in demand, the price of medium-size *Clarias* rose from about 10 baht/kg in the early 1970s to as much as 30 baht/kg in 1980 (see Appendix Table 3).

In theory, at least, the increase in price caused by excess demand should have induced a rise in production and a corresponding increase in supply. The recovery of the catfish-farming industry, however, has not been proceeding at the rate one would expect given the high and rising fish prices. Moreover, the mounting problems of this industry have discouraged the expansion of fish farming in general, and often frustrated government programs aimed at utilizing marginal lands and underemployed agricultural labor to alleviate regional protein deficiencies and to increase fish supplies in general through aquaculture. However, little has been done to this date to study the economics of catfish farming in Thailand. The few studies that occasionally appeared have been mainly descriptive, based on limited and probably unrepresentative samples.

Thus, an in-depth investigation of the economics of catfish production and marketing to determine farming practices and profitability and to identify key constraints is long overdue. Such a study would not only produce interesting analytical results, such as the technological coefficients of catfish production, the substitutability between inputs, economies of scale, etc., but would also yield useful data on the proper input and output mix under alternative behavioral and market assumptions, the optimal size of catfish farm, the optimal timing of harvest, the role of experience, etc., for policy formulation. The marginal products and returns to different factors could be compared with their opportunity cost to determine the social profitability of expanding catfish farming as compared to the alternative use of these factors. The effects of government policies such as tax incentives and subsidies on the industry could also be examined.

This list of research issues, though not exhaustive, is still too extensive to be covered in a single study such as the present one. However, before delineating the scope and limits of the present study, a brief review of previous research work is given to put the study in perspective.

PREVIOUS STUDIES

We know of six previous studies which have touched upon the subject of the economics of catfish production in Thailand. The main findings of these studies are summarized in

Table 1. Summary figures on catfish farming in Thailand based on earlier studies and corresponding figures of present study.

Studies[1]	Sample size (no. farms)	Average sample pond area (m^2)	Yield per crop (kg/m^2)	Stocking rates (fingerlings/m^2)	Feeding (kg/m^2 per crop)	Conversion ratio (feed/yield)	Culture period (months)	Mortality rate (%)
Pawapootanon (1965)	1	400	10.75	120	55.5	6.0:1	6	–
Inoue and Swegwan (1970)	2 'typical'	314	–	37 (1967) 228 (1969)	–	–	–	–
Kloke and Potaros (1975)[5]	4	480 to 4,000	5.8	200	13.43	3.5:1 to 4.8:1	3-6	40-50%
Tugsinavisuitti and Onchan (1977)	35	805[7] 4,711[8]	5.8	341	–	–	3.5-4.0	85
Division of Agricultural Economics (1977a)	7	1,842	6.4	246	33.8	5.3:1	4-5	86
Division of Agricultural Economics (1977b)[10]:								
Whole country	82	2,358	9.0	–	–	5.0:1	–	–
Central	22	3,400	–	265	–	–	–	–
NE	31	4,224	–	472	–	–	–	–
South	36	137	–	27	–	–	–	–
Present study (1979)	40	2,705	6.70	130	33.5	5.0:1	–	62

	Cost		Revenue		Profit			Cost combination (%)				
	฿/kg	฿/m^2	฿/kg	฿/m^2	฿/kg	฿/m^2	฿ per farm per crop	Feed	Fry	Labor	Others	Fixed
Pawapootanon (1965)	6.70[2]	72.00[2]	8.00	86.00	1.30[3]	14.00[3]	5,584[3]	19[4]	16[4]	55[4]	10[4]	–
Inoue and Swegwan (1970)	–	–	–	–	–	–	–	67	20	7	the balance	
Kloke and Potaros (1975)[5]	9.70	–	17.00	–	7.70	–	19,566 to 74,448	75	14	5	–	5[6]
Tugsinavisuitti and Onchan (1977)	12.93	75.50	14.02	81.40	1.09	5.9[9]	27,885[7]	70	21	1	the balance	2
Division of Agricultural Economics (1977a)	13.90	89.80	16.40	105.00	2.41	15.48	28,514	65	15	6.7	2	8
Division of Agricultural Economics (1977b)[10]:												
Whole country	10.78	–	14.90	–	4.12	–	87,700	–	–	–	–	–
Central	–	–	–	–	–	–	285,800	73	12	3	–	2
NE	–	–	–	–	–	–	–	60	23	5	–	2
South	–	–	–	–	–	–	–	56	23	9	–	2
Present study (1979)	15.90	107.14	19.50	130.62	3.54	13.76	63,500	71	11	3	9	6

[1] Studies 1-5 and 7 focused on farms in the Central Plain while study 6 covers the whole country except the North.

[2] Variable cost only.

[3] Gross less fixed cost.

[4] Fixed cost was excluded from the calculation and percentages are of total variable cost.

[5] Kloke and Potaros give no average cost, revenue and profit; the values reported above were calculated as simple averages of the lowest and highest values they report.

[6] Exclude opportunity cost of capital.

[7] Average pond size.

[8] Average farm size.

[9] Although the authors report losses, a close scrutiny of their figures reveals an oversight in deducting marketing costs from the farm-gate price instead of the Bangkok market price.

[10] Division of Agricultural Economics (1977b) gives figures per year; here they have been converted to per-crop basis by dividing 1.5, the estimated average number of crops per year.

Table 1 for comparison. However, any such comparisons should be made with caution, keeping in mind the differences in area, time, samples and definitions of variables. Table 1 is of particular usefulness as a historical background to the present study and provides a set of benchmark figures with which our results may be compared. Here we confine our discussion to the highlights of those earlier studies.

The reported average pond area per farm ranged between 300 m^2 to over 4,000 m^2, with later studies reporting higher figures, implying an increase in the average size of catfish farms over time. Regionally, the farms tend to be large in the northeast, somewhat smaller in the Central Plain and very small in the south. No information was available on the north where catfish culture is still quite rare. The reported yield, mainly based on samples taken from the Central Plain, ranges between 3.5 kg and 10.75 kg/m^2 per crop. One study by the Division of Agricultural Economics (1977b) reports an average yield of 9 kg/m^2 (computed from the average annual yield of 13.5 kg/m^2 divided by 1.5, the average number of crops raised per year), for the country as a whole. This figure appears unreasonably high, since all other studies (including ours) involving the Central Plain, the country's most productive area with relatively intensive culture, found an average yield between only 5 and 7 kg/m^2.

The reported stocking rates range from below 50 to over 400 fingerlings/m^2 with most 1970s studies for the Central Plain reporting figures around 250 fingerlings/m^2 compared to only 130 fingerlings/m^2 found by the present study. Information on feeding rates is more scant. Kloke and Potaros (1975) report feeding rates of 13 kg to 43 kg/m^2/crop, while the Division of Agricultural Economics (1977a) reports an average feeding rate of 33.8 kg/m^2, which compares with 33.5 kg/m^2 found by the present study. Two of the previous studies reported feed conversion ratios in the neighborhood of 5:1, which has also been found by the present study, although both higher (6:1) and lower estimates (3.5:1) have been reported. Culture periods ranging between 3 and 6 months and mortality rates between 40 and 86% were reported, compared with an average culture period of 4 months and a mortality rate of 60% found by the present study.

As expected, earlier studies reported lower costs and revenues per kg of production and per unit of pond area than more recent studies, at least partly due to inflation. If we take Kloke and Potaros (1975) as a benchmark, the cost of catfish production between 1975 and 1979 seems to have grown faster than the rate of inflation, while catfish prices have grown slower than inflation. If we, however, take the figures of the three 1977 studies as benchmark, both costs and price appear to have grown more or less in line with the rate of inflation. All studies report positive profits, on the average ranging between 1.09 baht and 4.12 baht/kg (compared to 3.54 baht/kg of our study), except for Kloke and Potaros (1975) who found catfish farming, on the average, considerably more profitable. On a per-farm basis, profits have been reported ranging between 5,000 baht in the mid-1960s to 285,000 baht in the mid-1970s. The latter figure reported by the Division of Agricultural Economics (1977b) is not corroborated by other mid-1970s studies which report profits between 20,000 baht and 75,000 baht per farm. The reason for the unusually high-profit data of the Division of Agricultural Economics (1977b) study is, as we have seen earlier, the unreasonably high estimate of the yield rather than an underestimate of cost or overestimate of price. The estimate of the present study is 63,000 baht per farm.

In terms of cost structure, there seems to be agreement among the various studies. Except for Pawapootanon (1965) who surveyed catfish farms in the environs of Bangkok during the earlier stages of development, all studies report that the cost of feed dominates (56 to 75%) the cost structure of the industry, followed by the cost of fry (11 to 21%). Labor and fixed costs each account for less than 10% of the total cost. The importance of labor, in particular, appears to have declined over time (Table 1). It must be repeated, however, that the above comparisons should be regarded with caution because of differences in location, sample size and general methodology. While earlier studies such as Inoue and

Swegwan (1970) encountered problems of over-production, falling catfish prices and farmer demands for a price support scheme, more recent studies, especially Kloke and Potaros (1975) and Tugsinavisuitti and Onchan (1977), encountered problems of spread of disease, rising cost of feed, especially trashfish and seasonality of fry availability. By comparison, the present study found the first two problems persisting while the third appeared more in the form of high mortality than seasonality of fry. Other problems identified by the present study are discussed in succeeding portions of this report.

SCOPE AND PLAN OF THE PRESENT STUDY

While the studies reviewed in the preceding section are useful in providing historical information on catfish culture in Thailand, they suffer from some serious limitations. First, all but two of these studies use a small, non-randomly chosen and (hence) non-representative sample of catfish culture in Thailand or in any particular region of the country. Second, due perhaps to miscalculations and double counting, the two statistically more valid surveys have obtained contradictory and conflicting results, one of them portraying catfish farming on the verge of bankruptcy and the other as one of the most lucrative industries in the country. Third, none of the studies to-date has analyzed in detail the prevailing farming practices, examined the role of experience and farm size in profitability, or attempted to estimate the parameters of production technology and examine the degree of efficiency in input use. Moreover, the results of earlier studies (the most recent pertains to 1976) are rendered obsolete by rising input costs and output prices. For example, between 1976 and 1980, the price of trashfish increased from 1.50 baht to about 3.00 baht/kg, fuel from 2.64 baht to 7.39 baht/liter, and the average price of catfish from 17.19 baht to 29.23 baht/kg.

Thus, there is a need for an up-to-date, rigorous study of the economics of catfish farming in Thailand based on a representative sample of catfish farms throughout the country, and of their activities throughout the year. Ideally such a study should be based on a farm-record-keeping survey rather than on recalled information.

Unfortunately, due to budget and time limitations as well as to the unavailability of an up-to-date reliable census of the catfish farms in the country, such an ideal was not attainable in the present study. Both spatial and subject-matter limitations had to be imposed. While catfish farming might be as prevalent in the northeast and in parts of the south as it is in the Central Region, for convenience we chose to focus again on the latter. Even within the Central Region we were not able to draw a random sample because of the wide distribution of catfish farms throughout the region and unavailability of (reliable) information on their location. We resorted to the selection of two provinces thought to be fairly representative of the region in terms of catfish culture: Suphan Buri, where intensive catfish culture has been practiced for years, and Nakhon Nayok, where extensive culture has recently been introduced. Moreover, the former with its high quality land and good water control and the latter with its successive droughts and floods and poor soil quality, form a fair cross-section of land and water conditions in the region.

In terms of subject matter, the present study focuses on the technology and economics of catfish culture from the fingerling stage to marketable size. Fry collection, hatchery operations, pond engineering, water chemistry and the biological aspects of catfish culture are not addressed, except to the extent that they impinge directly on the economics of catfish production. Similarly, the marketing of inputs and output is not dealt with to any depth. Moreover, certain issues that fall squarely within the domain of production economics such as input interaction and substitution, and demand and supply response to changing input and output prices are not adequately analyzed because of poor computational facilities and the inherent limitations of cross-section data (limited price variation).

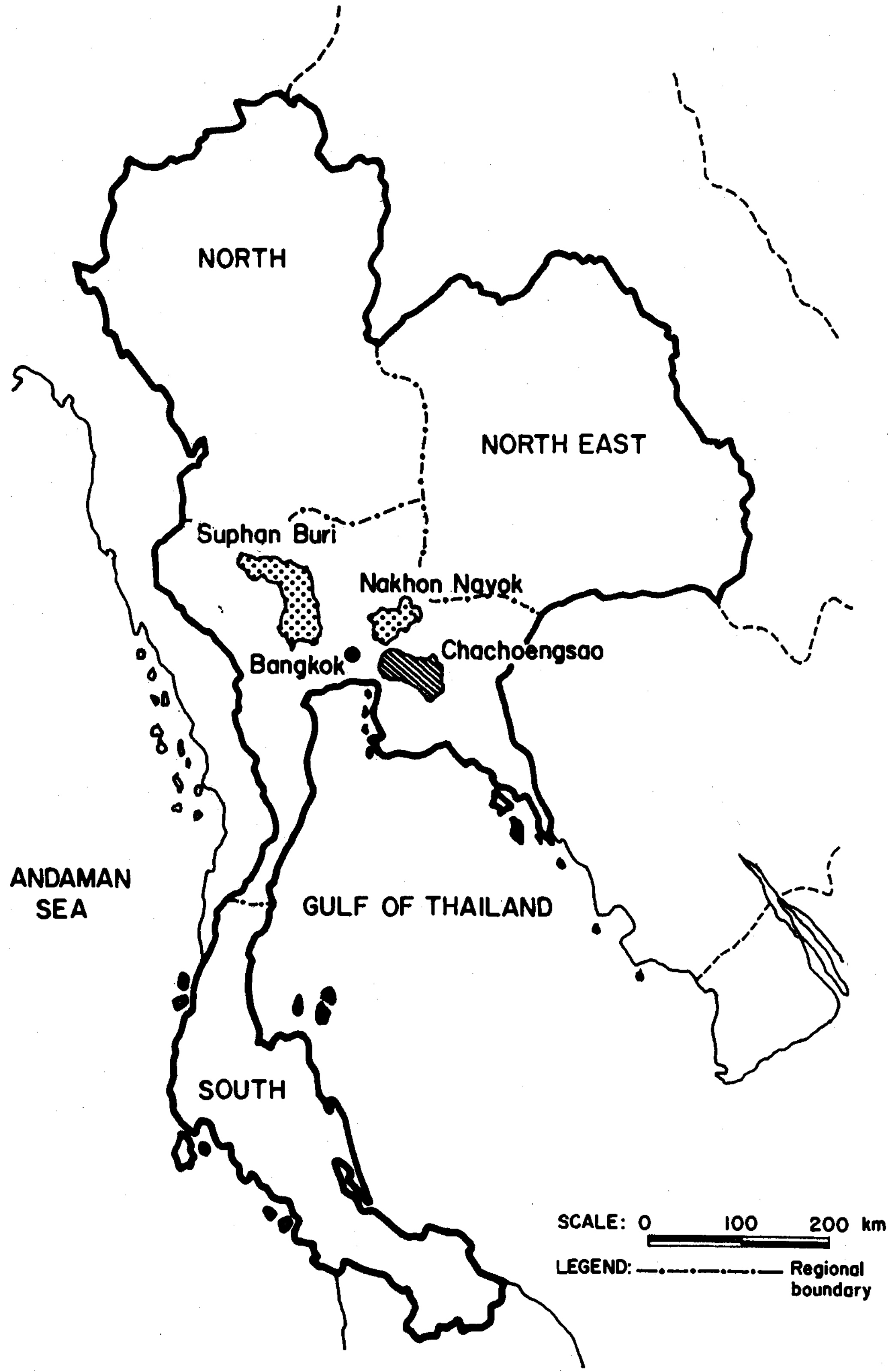

Fig. 1. Map of Thailand showing the study areas (dotted) and source of fry (shaded).

SELECTION OF SITES AND SAMPLES

As explained above, the provinces of Supha Buri and Nakhon Nayok were chosen as 'representative' sites of catfish culture in the Central Region (see map). A list of catfish farms in these two provinces was obtained from the provincial fishery offices but this information proved to be outdated; preliminary investigation indicated fewer catfish farms, more scattered in distribution than officially recorded.

Many farmers have given up fish farming or switched to the culture of other species such as snakehead fish *(Channa striata)* and tilapia, while others left their ponds idle because of losses from high mortality and rising costs. Those who remained in business were presumably the farmers with superior managerial ability and access to low-cost credit and other sources of investment funds or those with diversified operations that could spread the risk. Some farmers continued operations, despite losses, in anticipation of recovery through higher catfish prices which were expected to result from diminished supply and rising demand. Still others stayed in the business as long as they covered their operating costs, because of the high cost of switching to alternative crops. For instance, snakehead fish culture takes at least 8 months, too long for those who purchase inputs on credit. Switching back to rice production involves filling in the pond, an even costlier option.

Since over 50% of catfish farms in each province were reported to be concentrated in one or two districts, Amphoe Bang Pla Ma in Suphan Buri and Amphoes Ongkharak and Ban Na in Nakhon Nayok, it was decided to limit the survey to these three districts, attempting to interview as many farmers as possible. Our total sample of 41 farms is made up of 23 farms from Amphoe Bang Pla Ma of Suphan Buri and 18 farms from Nakhon Nayok amounting to about 80% of the farms in each district or roughly between 30 and 40% of the farms in each province. These two samples, while not randomly drawn, could be considered fairly representative of the farm population in each province. It is probably safe to say that the combined sample of the two provinces constitutes a fair cross-section of catfish farming in the Central Plain but little can be inferred from this sample about catfish culture in other regions of the country.

The survey was conducted during November 1979 and covered the last completed crop, which for most, but not all, farms was the June-September crop. The interviews were conducted by faculty members and students of the Department of Agricultural Economics, Kasetsart University. All figures obtained are based on owners'/farmers' recollection of their activities during the most recently completed crop.

Fish Farming Practices

BIOLOGY OF *CLARIAS BATRACHUS*

Catfish, in English, or *pla duk*, in Thai, is a generic name for a number of species belonging to the family Clariidae. Five are encountered in Thailand, two of which are popular sources of animal protein, *Clarias batrachus* and *Clarias macrocephalus*, locally known as *pla duk dan* and *pla duk oui*, respectively. Both are found in freshwater areas throughout the country; they can also live in brackishwater.

Thai consumers have a preference for *C. macrocephalus* but, because of bottlenecks in fry availability and slow growth, its culture is still limited in comparison to *C. batrachus*. Both species are distinguished by their ability to survive in a wide range of water conditions. They require a relatively small area for culture and can be stocked more densely than many other species, but tend to be susceptible to diseases when high density is combined with poor water quality. They can, however, live out of water for several hours, even days, or in waters of low oxygen content as they have accessory organs that enable them to breathe atmospheric air.

The diet of catfish is also wide-ranging; it includes worms, insects, shrimps and carrion (decayed matter). In the earlier years of their culture in Thailand, catfish were fed with household waste and by-products of canning factories, but more recently the diet consists of ground trashfish (from the trawl fishery) mixed with rice bran and boiled rice. Habitually the fish seeks its food near the water surface.

Clarias batrachus, the main catfish species cultured in Thailand, spawns during the rainy season between May and October; it may be induced to spawn throughout the year if new freshwater is available (Sidthimunka 1971). At present, fry are available from late January to November as a result of hatchery operations. The female catfish spawns when it reaches a length of 20 cm (one year old) by laying its eggs in a horizontal hole dug for this purpose on the bank below the water surface. The eggs hatch within 20 hours at a temperature between 25.0 and 32.2°C. While in earlier times the entire supply of catfish fry for stocking originated from natural waters, especially paddy fields and irrigation canals, an increasing number of fingerlings are now produced in hatcheries. Under 'average' culture conditions, 10-cm fingerlings stocked at the rate of $50/m^2$ reach an average length of 25 cm and weight of 200 gm after 4 months of culture (Sidthimunka 1971).

SOCIOECONOMIC FEATURES OF CATFISH FARMERS

In management-intensive, high-risk industries, such as fish farming, farmers' managerial ability becomes a deciding factor between handsome profits and bankruptcy. Managerial ability is, in turn, largely a function of the farmer's age and education as well as his experience and degree of involvement in fish farming.

Age distribution

With regard to age, we hypothesize that managerial ability is an inverted U-shaped function of age, being low and rising at a young age, leveling off around a maximum at middle age, and falling back to low levels at old age. Almost 80% of the sampled farmers were found to be intermediate in age (30 to 50 years); out of the sample of 41 farmers only three were less than 30 years old and six were over 50, with the eldest farmer being 58 years old (see Table 2 below). While this bell-shaped age distribution of farmers is not unusual with regard to the average age of the labor force, the middle-aged percentage is unexpectedly high (in Nakhon Nayok it is almost 90%) when compared with other socioeconomic groups, such as crop farmers and fishermen. For instance, in a recent study of coastal fishermen in Thailand (Panayotou et al. 1980) it was found that no more than 50% of the fishermen belong to the middle-aged group with the rest being distributed almost equally among the two other age groups.

The difference in age distribution between catfish farmers and other occupational groups may be attributable to *ex ante* or *ex post* selective participation in the industry: because of the possible importance of management ability (and perhaps other age-related requirements) of the industry, such as accumulated capital for investment, younger and older people may choose not to enter, or if they enter, few succeed and stay. The *ex post* selection may be more relevant to Suphan Buri, where the industry has a longer history, while *ex ante* selection may be the case in Nakhon Nayok, where catfish farming was introduced after the collapse of the industry elsewhere (especially in Suphan Buri). This collapse occurred during the mid-1970s and was the result of poor management, especially with respect to disease control and input substitution.

Educational background

Managerial ability and entrepreneurship are hypothesized to improve with level of education. At present, most farmers' literacy (75% have 7 years of primary education) could be considered adequate, but for improved farm management and use of new production technologies, a higher level of education is necessary. The willingness to take risks and innovate also may increase with the level of education. In comparison with small-scale fishermen and crop farmers, a smaller percentage of catfish farmers were illiterate and a larger percentage had attended a higher education on the average.

Catfish-farming experience

Experience in farming is thought to be an even more relevant indicator of managerial ability and hence of successful operation than either age or education. A farmer, switching from crop farming to fish culture, faces problems quite different from those of a farmer switching between crops. Pond design, water quality, disease control, feeding rates and output perishability are some of the problems peculiar to the fish farmer. Moreover, fish farming requires a different and more regular timetable of activities. In crop farming, planting and harvesting are the peak farm activities with little other effort required. In fish culture, the farm activities are spread throughout the rearing season. Stocking and harvesting may, in fact, require little effort by comparison to feeding, disease control and water management. An additional factor is the relatively short history of fish culture. Unlike rice, which has been farmed widely for centuries with the production technology being passed from

Table 2. Demographic and occupational characteristics for 41 catfish farmers in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farmers	%	Nakhon Nayok No. farmers	%	Total No. farmers	%
	23	100	18	100	41	100
Age (years)						
< 30	2	9	1	5.5	3	7
30-50	16	70	16	89	32	78
> 50	5	21	1	5.5	6	15
Average age	41.2 (9.6)[1]		41.1 (8.9)		41.2 (9.2)	
Education (years)						
Illiterate	1	4	5	28	6	14
Primary[2]	21	91	10	56	31	76
Secondary	1	4	3	17	4	10
Average education	4.5 (2.8)		4.4 (4.5)		4.5 (3.7)	
Experience[3] (years)						
1-5	11	48	17	94	28	68
6-10	6	26	1	6	7	17
> 10	6	26	–	–	6	15
Average experience	7 (3.8)		2.9 (2.0)		5.2 (3.8)	
Main occupation						
Catfish farming	18	78	4	22	22	54
Agriculture	3	13	7	39	10	24
Non-agriculture	2	9	7	39	9	22
Secondary occupation						
Fishfarming[4]	5	22	14	78	19	46
Agriculture	3	13	3	17	6	14
Non-agriculture	7	30	1	6	8	20
None	8	35	–	–	8	20
Previous occupation						
Agriculture	12	52	9	50	21	51
Non-agriculture	11	48	9	50	20	49
Reasons for catfish farming						
High returns	18	78	10	56	28	68
Trial	2	9	4	22	6	15
Idle inputs	13	13	4	22	7	17

[1] Figures in parentheses are standard deviations from the average.
[2] Four years of primary education were compulsory until recently when the period was extended to seven years.
[3] Experience in catfish farming.
[4] Includes catfish farming.

generation to generation, fish have not been farmed long enough or widely enough to accumulate an accepted body of common knowledge and practice among farmers. Learning by trial and error are still the main features of aquaculture both in Thailand and elsewhere in the developing world. Farmers in Suphan Buri had an average experience of about 7 years in catfish farming compared to almost 3 years for those in Nakhon Nayok. Around 25% of the sampled farmers in Suphan Buri had over 10 years of experience and more than half had been farming for at least 6 years. In Nakhon Nayok, virtually all farmers had entered the industry within the last 5 years with one-third being newcomers with only 1 year of experience. Only one farmer was a newcomer in Suphan Buri where the most experienced farmer had been raising catfish for the last 15 years (Table 2). The explanation for the experience differentials lies in the fact that Suphan Buri is generally a superior location for fish farming because of greater availability and control of water. Thus, the industry started first in Suphan Buri at a time when the price of catfish was too low to support the business in Nakhon Nayok, As the catfish diseases spread in Suphan Buri and other traditional farming areas and the use of insecticides increased throughout the country, the supply of catfish from farms and natural waters declined and catfish prices rose steeply (around the mid-1970s). It was then that catfish farming in Nakhon Nayok became economically profitable. The famers in this province opted for a "less intensive" culture than the one practiced in Suphan Buri, partly in an attempt to prevent the spreading of catfish diseases in their area and partly because of inferior land-water conditions. Encouraged by the profits of the first entrants, the rate of entry continues to be high. In contrast, the industry in Suphan Buri is dominated by the inveterate farmers; past failures, especially among the less experienced, have created a sort of barrier to entry.

Throughout the study, catfish culture in Suphan Buri is termed "intensive" and that of Nakhon Nayok "extensive" (or less intensive). However, these terms are not used in the conventional sense as found in aquaculture literature, that is, of relying on supplemental and natural feed, respectively. We use these terms in a loose and relative sense based on the stocking and feeding rates. We have observed that catfish farmers in Suphan Buri stock, on the average, more than twice as many fingerlings ($188/m^2$) than do farmers in Nakhon Nayok ($76/m^2$), and practice feeding rates 3 times higher. Moreover, average capital investment per square meter of pond area in Suphan Buri is almost three times that in Nakhon Nayok. While there is a 10 to 15% overlap in these measures of "intensity" between the two locations, we conveniently labelled Suphan Buri culture "intensive" and Nakhon "extensive", a usage corresponding to the layman's understanding of the structure of the industry.

Degree of specialization and occupational background

The degree of involvement or specialization in any particular occupation is a mixed blessing. On the one hand, specialization builds up managerial ability and skill; on the other hand, it increases risk. Often, farmers start growing a new crop on a trial, part-time basis, increasing their involvement and commitment of resources as they acquire more knowledge and skill. In high-risk activities like fish farming, however, diversification retains some advantages even at high levels of experience. Almost 80% of the sampled farmers in Suphan Buri had catfish as their main occupation compared to only 22% in Nakhon Nayok. Eight farmers in Suphan Buri practiced catfish farming as their only occupation compared to none in Nakhon Nayok (Table 2). The lower degree of specialization of Nakhon Nayok farmers may be explained partly by their limited experience in catfish farming and partly by the shorter period during which culture is possible in their province compared to Suphan Buri.

Among those who practiced catfish farming as their man occupation, non-agricultural activities as a secondary occupation were more prevalent in Suphan Buri than in Nakhon Nayok. In contrast, agriculture and non-agriculture were equally prevalent as main occupations among those who had fish farming as a secondary occupation in both locations. Diversification was also present within the fish farming occupation, as farmers attempted to use underutilized inputs and/or to reduce risk (especially risk arising from disease and market fluctuations) through the rearing of other species besides catfish, such as snakehead, striped catfish and tilapia. More than half the farmers in Suphan Buri and one-third of those in Nakhon Nayok raised other species concurrently with catfish.

The occupational background of catfish farmers in both locations was evenly divided between agriculture and non-agriculture (Table 2). Almost 80% of the sampled farmers in Suphan Buri gave "high returns" as the reason for their involvement in catfish farming while in Nakhon Nayok almost half had entered the catfish business either for trial or because of idle inputs. Ultimately, all catfish farmers were motivated by past or expected profitability, unlike rice farmers or small-scale fishermen who are to a large extent motivated by the "need for subsistence" or by tradition.

FARMS AND PONDS

Land ownership and farm size are important determinants of the incentives for investment, of the ability to obtain credit, and ultimately of household income. Securely-owned land may be used as a collateral for credit and, of course, the more land one owns the larger the amounts and easier the terms of loans one is able to secure. Insecure ownership (possession without title) or tenancy does not only reduce the ability to obtain credit but it further discourages investments in land improvement. Larger farms of high-quality, securely-owned land are expected to give rise to higher household incomes and, up to a point, may also give rise to economies of scale in production.

Land ownership and farm size

About two-thirds of the sampled farms in Suphan Buri and one-half in Nakhon Nayok owned land while the rest had either partial ownership or tenancy (see Table 3). The average farm size was larger in Nakhon Nayok (50.6 rai[1]) than in Suphan Buri (22.2 rai) where land was of better quality. Almost 70% of the farmers in Suphan Buri had land holdings smaller than 30 rai compared to about 45% for Nakhon Nayok. However, because of better quality of land, the average land value per farm was somewhat higher in Suphan Buri, although land accounted for a larger percentage of the value of farm assets in Nakhon Nayok because of the extensive type of farming practiced. The average value of total farm assets was 890,000 baht (US$44,500) in Suphan Buri and 738,000 baht (US$36,000) in Nakhon Nayok. Because of the relatively small size of farms and the management requirements of the operation, 85% of the farms were owner-operated. Only four farms in Suphan Buri and one in Nakhon Nayok had a caretaker or a crop-sharing arrangement (Table 3).

Farm location

Fish farms are usually located on the banks of canals or sub-canals to facilitate water supply and to avoid water pollution caused by use of pesticides and insecticides in fields between the source and the farm. Over 60% of the sampled catfish farms were within 50 m from a major canal or sub-canal; because of larger farm size and less-regular availability of water the percentage was considerably higher in Nakhon Nayok than for Suphan Buri (Table 4). Besides the distance from the water source, the drainage system, currents and winds are factors affecting farm location and pond structure. Farms located downstream are vulnerable to disease and water pollution originating upstream.

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[1]One rai = 1,600 m^2 (approximately).

Table 3. Farm size, land ownership and assets for 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	%	Nakhon Nayok No. farms	%	Total No. farms	%
	23	100	18	100	41	100
Farm size						
1-30 rai	20	87	8	44	28	68
31-60 rai	1	4	7	39	8	20
61-90 rai	–	–	2	11	2	5
> 90 rai	2	9	1	6	3	7
Average farm size (rai)	20.2 (32.5)[1]		50.6 (68.7)		33.5 (53.1)	
Land ownership						
Owned	15	65	10	56	25	61
Partially owned	1	4	3	17	4	10
Rented	7	30	5	27	12	29
Type of Enterprise						
Owner-operated	19	83	16	88	35	85
Partnership	–	–	1	6	1	2
Others (caretaker, rent, crop sharing)	4	17	1	6	5	13
Average farm assets (value)	'000 baht[2]	%	'000 baht	%	'000 baht	%
Land	513	58	483	66	1,000	61
Shelter and other buildings	180	20	158	21	338	21
Equipment	197	22	93	13	290	18
Total	890	100	738	100	1,628	100

[1] Figures in parentheses are standard deviations from the average.
[2] US$1 = 20.30 baht prior to July 1981 and 22.50 baht thereafter (approximately).

Pond area and average pond size

The pond area (water surface) used for catfish culture on individual farms during the survey ranged between 140 m^2 and 9,360 m^2 with an average of 2,361 m^2 in Suphan Buri and 3,125 m^2 in Nakhon Nayok. For the purpose of the analysis to follow, farms were divided into three groups according to their total pond area: small farms (up to 1,000 m^2), medium farms (1,001 to 3,000 m^2) and large farms (larger than 3,000 m^2). The sampled farms in each location were almost evenly distributed among the three size groups (see Table 4). Farm size here means total pond area, not the farm's total size.

Although the number of ponds per farm ranged from 1 to 13, only 25% had more than 3 ponds. The average pond size varied widely, ranging between 140 m^2 and 8,400 m^2, with an average size of 851 m^2 in Suphan Buri and of 1,138 m^2 in Nakhon Nayok (see Table 4). Larger ponds economize on land and construction cost but are generally more difficult to manage (apply feed, clean, maintain and harvest uniformly). Moreover, the risk associated with operating one large pond is relatively higher (as disease may wipe out an entire crop), and the flexibility in the selection of stocking and harvesting times is more limited than in the case of many smaller ponds.

Table 4. Pond location, number and size for 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	%	Nakhon Nayok No. farms	%	Total No. farms	%
	23	100	18	100	41	100
Distance from the source of water supply						
Main canal	13	57	11	61	24	58
1-50 m	10	44	7	39	17	41
> 50 m	3	13	4	22	7	17
Sub-canal	10	44	7	39	17	42
1-50 m	1	6	7	39	8	20
> 50 m	9	38	–	–	9	22
Pond area						
Up to 1,000 m^2	8	35	5	28	13	32
1,001-3,000 m^2	8	35	7	39	15	36
> 3,000 m^2	7	30	6	33	13	32
Average pond area (m^2)	2,290 (2,115)[1]		3,129 (2,872)		2,657 (2,478)	
Number of ponds						
1-3	17	77	13	73	30	74
4-6	2	9	1	5	3	8
7-9	2	9	1	5	3	8
> 9	1	5	3	17	4	10
Average pond size						
Up to 1,000 m^2	17	74	11	61	28	68
Up to 500 m^2	8	35	3	17	11	27
501-1,000 m^2	9	39	8	44	17	41
1,001-2,000 m^2	6	26	5	28	11	27
> 2,000 m^2	–	–	2	11	2	5
Average pond size (m^2)	851	(488)	1,138	(1,064)	977	(795)

[1] Figures in parentheses are standard deviations from the average.

Pond construction

Ponds were dug either by hand or with a bulldozer to a depth ranging from 1 m to 2 m at the outlet and 1 m or less at the opposite end (or water inlet) to facilitate drainage. The soil removed was used to erect dikes, dams and borders. In some cases, pond banks and water inlets were lined with bricks or stones to reduce erosion. Generally, ponds were not organized in a series. Each pond had its own water inlet and outlet to prevent the spread of disease through contaminated or toxic water. Virtually all ponds were for growout, i.e., to culture fingerlings to marketable size, with the exception of one farm in Nakhon Nayok which operated a hatchery as well.

STOCKING PRACTICES AND PROBLEMS

Stocking the pond with fingerlings involves three activities: pond preparation, seed procurement and the act of stocking. In the latter, two factors are of importance: stocking rate and stocking time.

Table 5. Pond preparation before stocking in 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	%	Nakhon Nayok No. farms	%	Total No. farms	%
	23	100	18	100	41	100
Pond cleaning						
Yes	22	96	17	94	39	95
No	1	4	1	6	2	5
Pond drying						
Yes	14	61	14	78	28	68
No	9	39	4	22	13	32
Pond treatment						
1. Salt						
Yes	14	61	1	6	15	37
No	9	39	17	94	26	63
2. Lime						
Yes	15	65	9	50	24	59
No	8	35	9	50	17	41
3. Other chemicals						
Yes	1	4	1	6	5	5
No	22	96	17	94	39	95

Pond preparation

Pond preparation before stocking is necessary to recover the fertility and chemical properties of the soil (e.g., reduction of toxicity) as well as to remove fish predators and other undesirable fauna. Pond preparation consists of (a) cleaning and drying after draining and (b) tilling and treatment through application of salt, lime, fertilizer and other chemicals. With two exceptions, all farmers cleaned their ponds before stocking; however, only two-thirds of them allowed sufficient time for the ponds to dry. The percentage of farmers drying their ponds was considerably higher in Nakhon Nayok than in Suphan Buri. With regard to pond treatment, approximately two-thirds of the farmers in Suphan Buri applied lime compared with 50% in Nakhon Nayok. Application of salt was practiced only in Suphan Buri; use of other chemicals and fertilizers was rare in both locations (see Table 5).

Seed procurement

The main sources of fingerlings for stocking were hatcheries and fry collectors from outside the two sampled catfish-growing areas, mainly from Chachoengsao Province (Table 6).

Secondary sources were local fry collectors in the two areas and a local hatchery in Nakhon Nayok. Only two Nakhon Nayok farmers reported obtaining fry from this hatchery, partly because of pre-emptive credit arrangements between farmers and catfish buyers who are often the suppliers of inputs such as fingerlings and feed.

Approximately half of the sampled farmers were satisfied with the quality and price of fingerlings. Among those farmers who had problems with fry, the major complaint was "high mortality rate" in Suphan Buri and "parasites" in Nakhon Nayok. Excessive fingerling

Table 6. Stocking material and practices in 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	%	Nakhon Nayok No. farms	%	Total No. farms	%
	23	100	18	100	41	100
Sources of fry						
Local collector	3	13	4	33	7	17
Other provincial supplier	20	87	9	50	29	71
Hatchery farm	–	–	2	11	2	5
Other	–	–	3	17	3	7
Problems with fry						
None	11	48	10	56	21	51
High mortality rate	10	43	–	–	10	24
Parasites	1	4	5	28	6	15
High price	1	4	1	6	2	5
Inadequate and late supply	–	–	2	11	2	5
Factors determing stocking rate						
Pond size	7	30	11	61	18	44
Last crop yield	4	17	–	–	4	10
Feed supply	3	13	–	–	3	7
Fry price	3	13	–	–	3	7
Working capital	2	9	–	–	2	5
Others	4	17	7	39	11	27
Fry cleaning before stocking						
Yes	4	17	5	28	9	22
No	19	83	13	72	32	78
Stocking frequency per crop						
Once	18	78	15	83	33	80
More than once	5	22	3	17	8	20
Timing criteria						
Weather condition	5	22	5	28	10	24
Fry availability	–	–	3	17	3	7
Other inputs availability	7	30	4	22	11	27
Neighbors' activities	2	9	3	17	5	12
Profitability	6	27	–	–	6	15
Others	3	13	3	17	6	15

prices and irregularity of supply were reported by only 4 farmers, three of whom operated in Nakhon Nayok (Table 6). This is somewhat surprising, considering there is a hatchery in that province.

Stocking rate

Although the Department of Fisheries recommends stocking rates of 60 to 100 fingerlings (7 to 10 cm long) per square meter of water surface, the actual stocking rates and fingerling sizes varied widely among catfish farmers. In Suphan Buri, stocking rates ranged between 45 and 400 fingerlings/m^2 ranging in size between 3 and 8 cm. These ranges were even wider in Nakhon Nayok: 3 to 437 fingerlings/m^2 and 2 to 23 cm, respectively. Farmers in Suphan Buri, using a variety of criteria, stocked an average of 188 fingerlings/m^2 (see

Table 11). Thirty percent of the farmers gave 'pond size' as their decision criterion and 17% based their decision on the last yield (see Table 6). It is notable that only 3 farmers out of 23 considered the price of fry as the decisive factor, and as many gave feed supply as their criterion. The rest of the farmers (26%) make reference to working capital limitations, copying the stocking rates of other farmers, etc. This last criterion was given by almost 40% of the farmers in Nakhon Nayok while the rest reported pond size as the yardstick determining stocking rates which averaged to about 76 fingerlings/m^2 of pond area. The average size of fingerlings stocked was 5 cm in Suphan Buri and 8 cm in Nakhon Nayok. The stocking of fewer and larger (older) fingerlings in Nakhon Nayok was the main reason for their higher survival rate—50%, compared to 34% in Suphan Buri (see Table 11).

Another reason for the higher survival in Nakhon Nayok might have been the fact that more farmers there cleaned and treated the fingerlings with formalin before stocking (see Table 6). The fisheries authorities recommend treatment with 220 ppm formalin for 20-25 minutes before stocking (Sidthimunka 1971).

Stocking time

For a number of reasons, such as fry availability and weather conditions, stocking cannot take place throughout the year. Stocking in December and January is precluded by the fact that fry are not available; spawning takes place during February to October (including induced spawning during February-April). Weather conditions are of more importance to Nakhon Nayok farmers because of poor irrigation systems resulting in low water levels before the rainy season, and flooding during the monsoon. No farmers in this province stocked in February, April or July. This does not mean that during the remaining months stocking was possible throughout the province, the specific location (and elevation) of the farm in relation to the water source made stocking possible in certain farms but not in others.

Besides location, economic considerations may have determined stocking time. As farmers have observed that catfish prices tend to be low in the first and last quarters of the year, they choose to stock their ponds at such a time that the fish could be harvested when the prices peak in mid-year. Thus, over 75% of the farms in Suphan Buri stocked during February-April and harvested during May-August. The peak month for stocking was March when 45% of all ponds were stocked; the peak month for harvest was July when 32% of all ponds were harvested. In Nakhon Nayok, two-thirds of the ponds were stocked in May-June with half of these being harvested 3 months later (in August). The later stocking time and shorter growing period of Nakhon Nayok may be due, respectively, to the water paucity before the rainy season and the floods during the September monsoon, coupled with an attempt to harvest while the catfish prices were still high. This may also explain the low stocking rates in Nakhon Nayok: higher stock density would reduce individual growth below the rate necessary for fish to reach marketable size by harvesting time. The economics of stocking and harvesting time is further analyzed below.

Farmers, when asked the main criteria for selecting their stocking time, gave a variety of (not unrelated) reasons ranging from weather conditions and imitation of neighbors to input availability (especially fry and family labor) and profitability. While none of these criteria was strikingly dominant, input availability (other than fry) was given by over 30% of the farmers in Suphan Buri, and profitability by over 25% of the farmers in the same province. A somewhat different response was obtained from Nakhon Nayok where almost 30% of the farmers indicated weather conditions and almost 40% input availability (including fry) as their main criteria in choosing optimum stocking time (Table 6). It might be worth noting that no farmer in Nakhon Nayok considered profitability as a key factor in deciding stocking time (due perhaps to the limited range of options) although the criteria used do have an indirect bearing on profits.

About 80% of the farmers in each location stocked their ponds only once per crop, as is officially recommended. The rest stocked more than once in an attempt to compensate for the high mortality or to supplement an inadequate supply of fingerlings during the first stocking. Preferred stocking time during the day was early morning or late afternoon.

FEEDING PRACTICES AND PROBLEMS

The availability of abundant supplies of low-priced feed in the form of trashfish from the trawl fishery was a key factor in the rapid development of catfish farming during the late 1960s and early 1970s. As the industry came to rely for feed almost exclusively on trashfish, the ensuing doubling and tripling of its price under increasing demand from fish-meal plants (and catfish farmers) caused a near collapse of the industry during the mid-1970s. The problem was further exacerbated by the spread of catfish diseases, not unrelated to the use of trashfish, especially with intensive-feeding rates. Farmers did attempt to modify their feeding rates and feeding formulas, and in some cases replaced trashfish by manufactured animal feed. Many were forced to leave the industry while the rest were saved by the ensuing catfish price increases and by superior management abilities. However, the problems of disease, rising costs of trashfish and lack of suitable substitutes persist. A close examination of prevailing feeding practices (feed-mix, feeding rates), as well as of farmers' perception of the problems and response to changing prices, is prerequisite to finding a workable solution.

Feed-mix

The feed-mix is not uniform throughout the rearing period. During the first two weeks after stocking, the fingerlings are fed, usually in early morning or late afternoon, with ground trashfish (sometimes mixed with a little rice bran). Subsequently, trashfish is mixed with rice bran and (boiled) broken rice and the mixture is ground to form a sticky paste. The proportions of rice bran and broken rice are increased as the harvest approaches in order to induce rapid fattening of catfish. The average feed mix over the entire growing period varied among farmers in the same location but more significant differences were observed between locations. In Suphan Buri, the average feed proportions were 10 parts of trashfish, 2 parts of rice bran and 1 part of broken rice by weight while in Nakhon Nayok the corresponding proportions were 3:1:1 (Table 11). The figures for Suphan Buri corroborate earlier findings (Kloke and Potaros 1975) for feed-mix over the two months prior to harvest.

More than 80% of the farmers in Nakhon Nayok (compared to 65% in Suphan Buri) complained of trashfish-induced water pollution, apparently the result of poor drainage in larger ponds (Table 7). A second factor for using a smaller proportion of trashfish in Nakhon Nayok could be a conscious effort by the first few farmers there to avoid the disease problems of Suphan Buri. This effort which is reflected in lower stocking and feeding rates as well as different composition of feed was imitated by newcomers; 50% of the farmers, especially new entrants, reported imitating their neighbors' feeding practices. Moreover, the trashfish protein supplied by the farmers may have been further supplemented by natural food in the form of worms, insects and other organisms available in greater quantities under extensive culture. When questioned on their feed-mix criteria, Nakhon Nayok farmers rejected both the relative prices of the ingredients and the conversion ratio of the mixture, reporting stickiness of the mixture and imitiation of neighbors as deciding factors (see Table 7).

Suphan Buri farmers, on the other hand, appeared more cost-conscious as 60% reported considering feed prices and the feed conversion ratio as their main criteria in deciding the feed mix. At the same time over 25% of them listed the high cost of trashfish as a more serious problem than trashfish-induced water pollution. Although Suphan Buri farmers used proportionately more trashfish in the feed-mix than their colleagues in Nakhon Nayok, all without exception used all three conventional feed ingredients (trashfish, rice bran and broken rice). In contrast, more than one-third of Nakhon Nayok farmers were experimenting with partial combinations such as trashfish only, and trashfish and rice bran. On the other hand, while no farmer in Suphan Buri experimented with feed formulas containing less than 65% trashfish, there were at least 4 farmers in Nakhon Nayok using feed combinations with less than 40% trashfish. As expected, extensive culture allows a wider spectrum of choices in the combination of feeds and other variable inputs than intensive culture (Table 7).

Because of the perishability and high risk associated with contaminated trashfish, it is essential to identify the sources of trashfish. The presumption here is that farmers who (have the means to) buy their trashfish directly from the landing port are able to obtain better-quality feed than those who rely on merchants or other farmers to supply them with trashfish. This, in turn, highlights the importance of the scale of farming operation (or size of fish farm), the ownership and use of farm-owned transportation. Our survey revealed that about 50% of the farms in each location purchased their trashfish directly from the Mahachai landing port, 40% relied on local merchants—mainly large-scale catfish farmers—and the rest bought feed from provincial traders (Table 7).

Feeding rates

Feeding rates affect both fish growth and fish mortality. At both very low and very high feeding rates, mortality occurs because of starvation and water pollution, respectively. In between, there is a wide spectrum of feeding rates which result in varying growth rates. Within this range, as the feeding rate increases, both growth and cost rise. At high feeding rates, cost rises relatively faster than growth as feed conversion ratios worsen (it takes increasing quantities of feed to produce an additional unit of body-weight when growth rates are already high) and oxygen depletion problems occur, requiring higher fuel costs to maintain a given level of water quality. Thus, there is an optimum feeding rate per unit of time depending on the size and growth of fish as well as an overall feeding rate per unit of pond area during the entire growing period that maximizes the net value of the operation. This latter rate should be determined simultaneously with the stocking and harvesting times.

About two-thirds of the sampled fish farmers determined their feeding rate through observation of feed consumption (Table 7). This trial-and-error method carries with it the danger of overfeeding with consequent waste and low oxygen levels.

To deal with these problems one-third of the farmers determined the daily quantity according to the age of the fish, for example, starting at 0.2 gm per fingerling after stocking and increasing the feed daily at such a rate that it roughly doubles every two weeks. The problem with this practice is that, besides age and feed, it makes no allowance for other factors, such as stocking density and water quality, which affect growth and hence feed requirements. Another approach for determining feeding rates is the officially recommended formula of 5% of body weight per day; however, only one farmer in Nakhon Nayok and no farmer in Suphan Buri used this formula (Table 7). The major problem with this method is the difficulty in estimating the biomass and average weight. It is worth noting for comparison that catfish farmers in Alabama used analogous formulas: 53% used consumption methods; 25% used age-charts and the rest used either 3% of body weight or simply made guesses as to the appropriate feeding rate (Adrian and McCoy 1972).

Table 7. Feeding practices and problems in 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	Suphan Buri %	Nakhon Nayok No. farms	Nakhon Nayok %	Total No. farms	Total %
	23	100	18	100	41	100
Feed content						
Trashfish	–	–	1	6	1	2
Trashfish and rice bran	–	–	5	28	5	12
Trashfish, rice bran and broken rice	23	100	12	67	35	86
Source of trashfish						
Local merchants/farmers	11	48	10	55	21	51
Directly from landing port[1]	9	40	7	39	16	39
Provincial merchants	3	12	1	6	4	10
Factors in feed mixture						
Stickiness	8	35	12	67	20	49
Feed price	10	43	–	–	10	24
Conversion ratio	4	17	–	–	4	10
Others (e.g., imitation of neighbors)	1	4	6	23	7	7
Determination of daily quantity						
Change according to age of fish	7	30	6	33	13	32
5% of fish weight	–	–	1	6	1	2
Observation of feed consumption	16	70	11	61	27	66
Source of information about feeding						
Experience	17	74	9	50	26	63
Neighbors	4	13	8	44	12	29
Others	2	9	1	6	3	8
Main problems in feed supply						
High cost	5	22	13	72	18	44
Decayed trashfish	2	9	1	6	3	7
None	16	70	4	22	20	49
Main problems in using trashfish						
Water pollution	15	65	15	83	30	73
High cost	6	26	2	11	8	20
Others	2	9	1	6	3	7
Supplemental feed						
Artificial feed	5	22	3	17	8	20
Vitamins	13	57	3	17	16	39
Others	–	–	4	22	4	10
None	5	22	8	44	13	31
Intention to use artificial feed as a substitute for trashfish						
Yes, because	1	4	5	28	6	15
difficult to get trashfish	–	–	2	11	2	5
save labor	1	4	2	11	3	7
grow faster	–	–	1	6	1	3
No, because of	22	96	13	72	35	85
lack of information	6	26	3	17	9	22
high cost	4	17	8	44	12	29
cannot substitute (does not work)	12	52	2	11	14	34
The farmers' response to increasing trashfish prices						
1. Feed combination (short-run)						
Change	6	26	4	22	10	24
No change	17	74	14	78	31	76
2. Catfish farming (long-run)						
Continue	7	30	8	44	15	37
Quit	12	52	8	44	20	49
Not certain	4	17	2	11	6	14

[1] From fish merchants at Mahachai landing port.

Independently of the formula used to determine the appropriate feeding rate, most farmers tried to avoid daily rates in excess of 0.5 kg of feed/m^2 as higher rates were believed to result in water pollution. While there were only 4 farmers in Suphan Buri and 2 in Nakhon Nayok who averaged a higher daily feeding rate over the culture period, more must have done so during the last few weeks of culture, especially those with high stocking and high survival rates. The average daily feeding rate, over the culture period, was 0.39 kg/m^2 in Suphan Buri and only 0.16 kg/m^2 in Nakhon Nayok (Table 11).

Manufactured feed as a substitute for trashfish

Considering the rising costs of trashfish and the problems associated with its use we investigated farmers' response to changing prices and their attitudes towards using manufactured feed as a substitute. Although 5 farmers in Suphan Buri were already using some manufactured feed along with the conventional feed-mix, only 1 farmer thought that this type of feed could be used as a substitute for trashfish. Over 50% of the sampled farmers in this province stated categorically that they are convinced that "it won't work." Half as many admitted total ignorance, while 4 farmers considered the cost of manufactured food too high to replace trashfish (Table 7).

Farmers in Nakhon Nayok were more optimistic. Although only 3 farmers were using manufactured feed as a supplement at the time, as many as 13 farmers thought a subtitution might be workable but 8 of them pointed to its high cost as a discouraging factor. Only 2 farmers rejected the idea as unworkable; 3 admitted ignorance. It is somewhat surprising that those who expressed the intention to substitute artificial feed for trashfish gave as justification saving labor and difficulties in obtaining trashfish rather than water pollution, of which they complained earlier, apparently anticipating continuation of pollution problems even after the substitution.

Farmers' response to rising trashfish prices was overwhelmingly (75%) in favor of maintaining the present feed combination unchanged. However, 50% added that if the price of trashfish keeps rising, they will quit the business altogether. More of the farmers in Nakhon Nayok (44%) than in Suphan Buri (30%) were determined to continue catfish farming under a situation of escalating trashfish prices (Table 7).

DISEASE AND TREATMENT

In catfish culture, diseases tend to spread relatively easily because of (a) the high density of stocking and intensity of feeding in a limited water area, (b) the proliferation of disease agents through the common water source, between ponds, farms and locations, (c) the type of feed used and (d) the high vulnerability of the species. As a result, the risk of a complete loss of a crop tends to be higher than in other agricultural activities. Moreover, externality problems arise when upstream farms release contaminated water into the main water source, spreading diseases and parasites downstream. Mortality also tends to be high, especially during the first few weeks after stocking, because of parasites carried by the fingerlings from the hatcheries to the rearing ponds. Another cause of disease and mortality may be contaminated trashfish and inappropriate feed-mix.

Only 4 farmers, all from Nakhon Nayok, reported no disease problems. The predominant disease symptom, reported by 56% of all farmers, was a combination of lesions and swelling of the area near the pectoral fin base (Table 8). These symptoms were observed by 83% of Suphan Buri farmers and only 22% of those in Nakhon Nayok, where the most common symptom was swelling in the area near the pectoral fin without the appearance of lesions. Three farmers in Suphan Buri reported a similar problem while 2 farmers in Nakhon Nayok reported incidences of abdominal dropsy.

Farmers' reaction to the appearance of disease symptoms was overwhelmingly in favor of medication.[2] About 80% of all sampled farmers reported using some medicine in the feed such as terramycin, or oxytetracycline in the case of disease and treatment with formalin in the case of parasites. From the 19 farmers in Suphan Buri using medication only 12 were convinced of its effectiveness, while in Nakhon Nayok all 13 farmers using medication thought it was effective (Table 8). The few who used no medication (because they were convinced of its ineffectiveness) confined their treatment to removal of the infected fish (1 farmer in Nakhon Nayok) and change of the water (2 farmers in Suphan Buri).

While such was their immediate (current crop) reaction to disease, in the long-run (new crop) farmers favor a combination of medication and higher stocking rates to compensate for expected mortality. Many Suphan Buri farmers, being unconvinced of the effectiveness of medication, were relying more heavily on higher stocking rates to compensate for high mortality. Over 80% of all farmers, however, had or were prepared to apply, salt and lime as preventative/curative measures[3] (Table 8).

In terms of medical expenses Suphan Buri farmers spent almost eight times as much per m^2 of pond area and three times as much per kg of fish produced as Nakhon Nayok farmers. However, in terms of fuel mainly for water changes, the latter consumed twice as much per m^2, five times as much per fingerling and almost seven times as much per kg of feed used as the former (see Table 12 below). This comparison suggests the possibility of substitution between medication and water change; as shown in Table 8, disease was less prevalent in Nakhon Nayok (78%) than in Suphan Buri (100%).

The principal sources of information on treatment were neighbors, involving about 45% of the farmers in each location. This fact might be responsible for the observed duplication of misguided practices such as the increase of the already high stocking rates to compensate for high mortality. About 25% of the farmers obtained information on disease treatment from merchants and 10% from government officials, as shown in Table 8.

On the subject of government assistance, more than half of the farmers in Nakhon Nayok and about one-third of those in Suphan Buri reported obtaining some service from the Provincial Fishery Station. The lower figure for Suphan Buri might be due to the fact that only recently has a fishery station begun operating in that province.

HARVEST AND MARKET OUTLETS

The culture period ranged between 2 and 8 months, averaging 4.1 months in Suphan Buri and 3.6 months in Nakhon Nayok (Table 11). Two-thirds of the farmers, however, were in favor of shorter culture, 3-4 months in Suphan Buri and 2-3 months in Nakhon Nayok. Buyers usually carried out the harvesting. Within each location, there was no clear relationship between length of culture period and yield in terms of weight/m^2. For instance, the two most successful farmers in each location kept the fish in the pond for the same length of time as the two least successful farmers. As we have seen earlier, the main factors determining the timing and length of culture period were the availability of fry and water,

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[2] This does not mean that they did not take other steps such as change of water, but that they consider medication as more important in this respect.

[3] The farmers did not regard salt and lime to be medication as such, but a part of the general preparation of the pond for stocking.

Table 8. Disease and treatment in 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	Suphan Buri %	Nakhon Nayok No. farms	Nakhon Nayok %	Total No. farms	Total %
	23	100	18	100	41	100
Types of disease						
Hemorrhagic septicemia						
Swelling in the area near the pectoral fin	3	13	8	44	11	27
Lesion	1	4	–	–	1	2
Both swelling and lesion	19	83	4	22	23	56
Abdominal dropsy	–	–	2	11	2	5
No disease	–	–	4	22	4	10
Treatment (current crop)						
Medication	21	92	13	72	34	83
Remove infected fish	–	–	1	6	1	2
Change water	2	9	–	–	2	5
None	–	–	4	22	4	10
Efficiency of medical treatment						
Effective	12	52	13	72	25	61
Ineffective	4	17	1	6	5	12
Not certain	7	30	4	22	11	27
Response to disease: medical treatment vs. higher stocking rates[1]						
Higher stocking rate	1	3	–	–	1	2
Both (with emphasis on stocking)	4	17	–	–	4	10
Both (equally)	15	65	17	94[2]	32	79
Not certain	3	13	–	–	3	7
Not available	–	–	1	6	1	2
Lime application						
Yes	20	87	15	83	35	85
No	3	13	3	17	6	15
Salt application						
Yes	20	87	13	72	33	80
No	3	13	5	28	8	20
Sources of information on treatment						
Neighbor	11	48	8	44	19	46
Government officer	4	17	4	22	8	20
Merchant	6	26	4	22	10	24
Others	2	9	2	11	4	10
Service from fishery station						
Yes	8	35	10	56	18	44
No	15	65	8	44	23	56

[1]Includes both higher stocking rates in anticipation of mortality as well as replacement after mortality occurs (if during the first few weeks of the culture period).

[2]Includes 3 farmers who had no disease problems but were taking precautionary measures.

the expected behavior of catfish prices through the year and the time necessary to raise the stocked fingerlings to marketable size given the intensity of culture practiced. Market size is 200 to 250 g.

Once the fish has reached a marketable size, the optimum harvesting time should depend on the (marginal) benefit from keeping the fish one more day in the pond compared to the corresponding marginal cost in terms of feed, foregone interest, the probability of disease, and possible delay of the next crop. On the other hand, factors such as availability of buyers, preemptive marketing arrangement with creditors, and need for cash may limit the farmer's choice of optimum harvesting time on strictly economic factors.

More than 90% of the sampled farmers decided on harvesting time on the basis of the average size of fish in the pond. Only 3 farmers were using the price of fish as the main criterion (Table 10). There are good reasons for this approach. First, catfish prices reach a peak at mid-year and remain fairly stable during the main harvesting months. Over the period 1967-79, catfish prices averaged 14.28 baht per kilogram in June, 14.37 baht in July and August 14.58 baht. Also, when catfish reach marketable size of about 200 g, their unit price does not increase in proportion to size of fish harvested; considerably larger fish (400 g) do command a higher price but the feed requirements are considerable and rising while growth rate slows down. Thus, the size of fish is a good proxy of the economics of harvesting time as it embodies both price and cost considerations. Fear of disease and the necessity to purchase feed on credit, however, may bias the choice in favor of an early harvest.

Over 90% of the farmers harvested their crop by draining the ponds; the rest used nets. The advantage of the first method is its low harvesting cost (especially labor) while the second allows selective harvesting.

As catfish have been in short supply in recent years while demand has risen steadily, there has been no shortage of buyers. Less than 20% of the farmers sold to a particular buyer because of some obligation, such as debt and or purchase of inputs on credit as shown in Table 9.

There was a variety of market outlets ranging from local trashfish suppliers through wholesalers to the Fish Marketing Organization (FMO). The dominant outlets for Suphan Buri catfish production were the local trashfish suppliers (30%), the provincial wholesalers (22%) and wholesalers from other provinces (17%). In the case of Nakhon Nayok, 50% of the farmers sold the bulk of their crop to wholesalers from other provinces (other than their own or Bangkok); 22% sold to local trashfish suppliers and 17% to FMO. The role of Bangkok wholesalers was very limited. Only 2 farmers, one in each location did any fish processing (fermentation) at home (Table 9).

All but one of the Suphan Buri farmers were content with the price they received, compared to 60% in Nakhon Nayok. No significant differences were found between the two locations with regard to type of payment; about 60% of the farmers were paid in cash, 30% on credit, and the rest a combination of the two. Again, the main sources of market information on catfish prices were merchants and neighbors, as shown in Table 9.

There was no significant difference in catfish prices between the two location: prices ranged between 13.00 and 22.00 baht/kg in each location, averaging 18.50 baht in Suphan Buri and 16.90 baht in Nakhon Nayok. The weighted average was 19.41 baht in the former and 19.69 baht/kg in the latter.

As expected, the intensive culture of Suphan Buri gave a higher average yield, 9.56 kg/m^2, than the extensive culture of Nakhon Nayok, 4.06 kg/m^2 (Table 11).The variances were large, since the yield ranged from 1.7 kg to 20.3 kg/m^2 in the former and from 0.1 kg to 12.2 kg/m^2 in the latter.

CREDIT

More than 50% of sampled farmers had borrowed funds towards financing their catfish farming operations. The percentage was somewhat higher for Nakhon Nayok where many farmers relied more on trashfish suppliers than on banking institutions for loans and (hence)

Table 9. Harvest and sale of fish produced in 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

Item	Suphan Buri No. farms	Suphan Buri %	Nakhon Nayok No. farms	Nakhon Nayok %	Total No. farms	Total %
	23	100	18	100	41	100
Harvesting method						
By draining the pond	21	91	17	94	38	93
Using net	2	9	1	6	3	7
Main factor determining harvesting time						
Fish size	22	96	16	89	38	93
Fish price	1	4	2	11	3	7
Fish processing (fermentation)						
Yes	1	4	1	6	2	5
No	22	96	17	94	39	5
Catfish buyers (major buyers)						
Local trashfish supplier	7	30	4	22	11	27
Provincial trashfish supplier	2	9	–		2	5
Fish Marketing Organization	3	13	3	17	6	15
Bangkok wholesaler	2	9	–		2	5
Provincial wholesaler	5	22	2	11	7	17
Wholesaler from other provinces (excluding Bangkok)	4	17	9	50	13	31
Sale obligation						
Yes	6	26	3	17	9	22
Loan	2	9	1	6	3	7
Inputs on credit	3	13	2	11	5	12
Gratitude	1	4	–	–	1	3
None	17	74	15	83	32	78
Farm price						
Fair	22	96	11	61	33	80
Unfair	1	4	7	39	8	20
Payment						
Cash	13	57	11	61	24	59
Credit	7	30	5	28	12	29
Both (more than one sale)	3	13	2	11	5	12
Sources of price information						
Merchant	10	43	10	56	20	49
Neighbor	11	48	5	28	16	39
Fish Marketing Organization	2	9	1	6	3	5
Town market	–	–	2	11	2	7

had to pay non-institutional interest rates of 15 to 36%. In contrast, Suphan Buri farmers borrowed mainly from banks, paying the institutional rates of 12 to 15% (Table 10).

About two-thirds of the sampled Suphan Buri farmers and half of those in Nakhon Nayok reported no need for borrowing in the near future. Three farmers in each location were seeking small loans up to 100,000 baht, while 5 farmers in each location were seeking medium, up to 500,000 baht and large loans, over 500,000 baht.

Table 10. Current loans and credit needs of 41 catfish farms in Suphan Buri and Nakhon Nayok Provinces of Thailand, 1979.

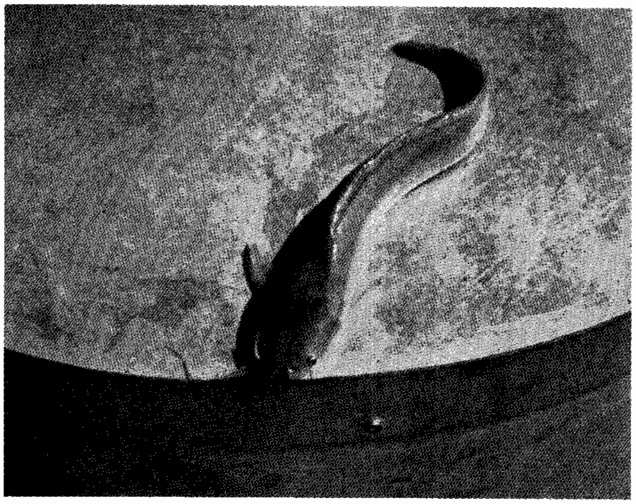
Item	Suphan Buri No. farms	Suphan Buri %	Nakhon Nayok No. farms	Nakhon Nayok %	Total No. farms	Total %
	23	100	18	100	41	100
Borrowing						
Yes	10	43	11	61	21	51
No	13	57	7	39	20	49
Sources of credit						
Banking institution	6	27	4	22	10	24
Trashfish suppliers, etc.	3	13	5	28	8	20
Both	1	4	2	11	3	7
Interest rate						
1. Institutional						
12%	4	17	4	22	8	20
15%	3	13	2	11	5	12
2. Non-institutional						
< 15%	2	9	1	6	3	7
15-24%	–	–	5	28	5	12
> 24%	1	4	1	6	2	5
Required credit						
None	15	65	9	50	24	59
< 100,000 baht	3	13	3	17	6	15
100,000-500,000 baht	5	22	1	6	6	15
> 500,000 baht	–	–	5	28	5	12

Table 11. Average yield and input use by location in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

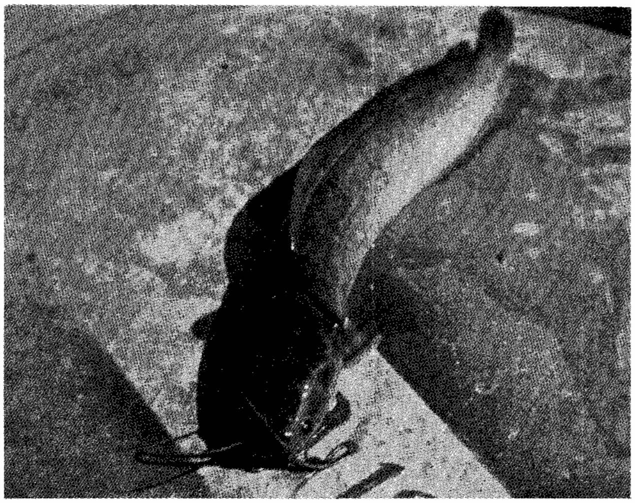
Item	Suphan Buri	Nakhon Nayok	Average
Sample size	22	18	
Average farm size (m^2 pond area)	2,361	3,125	2,705
Average yield (kg/m^2)	9.56	4.06	6.70
Stocking rate (fingerlings/m^2)	188.00	76.00	130.00
Feeding rate (kg/m^2/crop)	51.17	17.17	33.49
Feed/stocking ratio (kg/fingerling)	0.27	0.23	0.26
Feed-mix: - trashfish (% by weight)	77.87	62.12	73.67
rice bran (% by weight)	14.17	17.84	16.20
broken rice (% by weight)	7.96	20.04	10.13
Artificial feed (baht/m^2)	0.33	0.28	0.30
Conversion ratio (feed/yield)	5.35	4.23	5.00
Survival rate (%)	33.61	49.45	38.17
Medicine (baht/m^2)	2.96	0.38	1.62
Fuel use: (liters/m^2)	0.35	0.77	0.56
(liters/100 fingerlings)	0.14	1.01	0.43
(liters/100 kg feed)	0.68	4.47	1.69
Family labor (man-hours/m^2)	0.27	0.11	0.19
Pond investment (baht/m^2)	5.53	5.18	5.35
Investment in facilities (baht/m^2)	25.35	9.22	16.97
Culture period (months)	4.09	3.58	3.86
Cropping intensity (crops/year)	1.36	1.44	1.40
Farmers' experience (years)	6.90	2.90	5.10

Thailand Catfish Farming in Pictures

Photographs by the authors



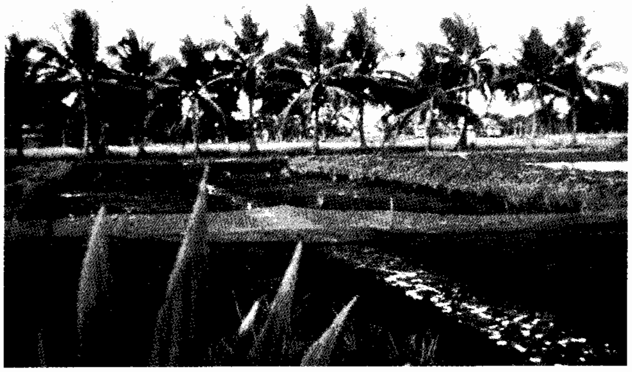
Clarias batrachus, the most commonly cultured catfish in Thailand.



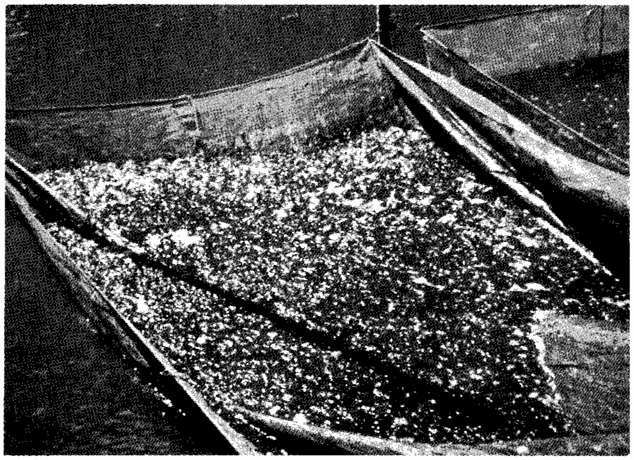
Clarias macrocephalus, another species of catfish found in natural freshwater sources. Only a few farms culture it because fry are scarce.

Hatchery field for *Clarias batrachus* which can induce catfish to spawn up to 10 times during a year.

Holes are dug along the dike to provide nests for the breeding fish.



This nursery is 1-m deep at one end and 1.5 m at the other to allow draining of water. When full the water level in the pond is between 25 and 50 cm.

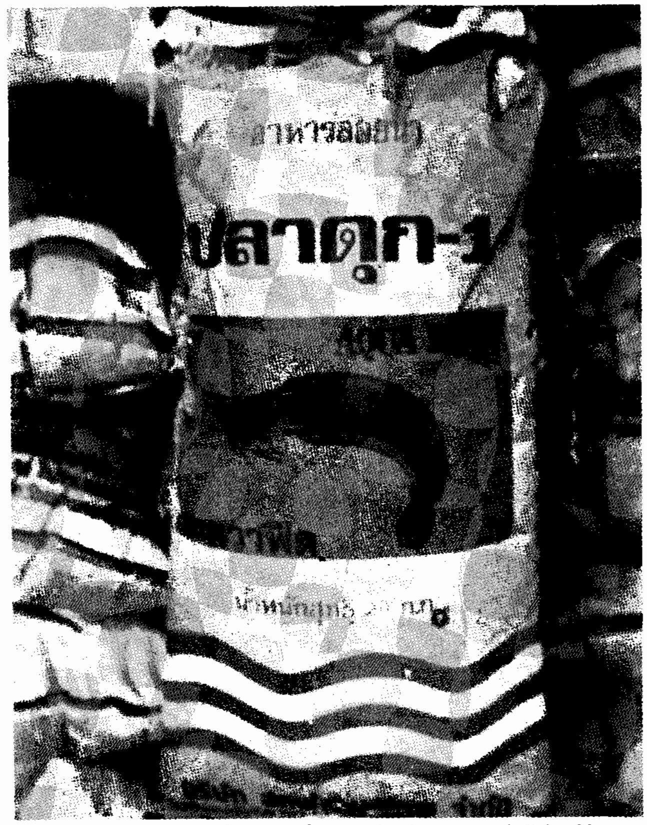


Fingerlings are gathered by net for distribution to catfish farms throughout the country.

Trashfish, the major component of feed, is delivered to the farm every day.

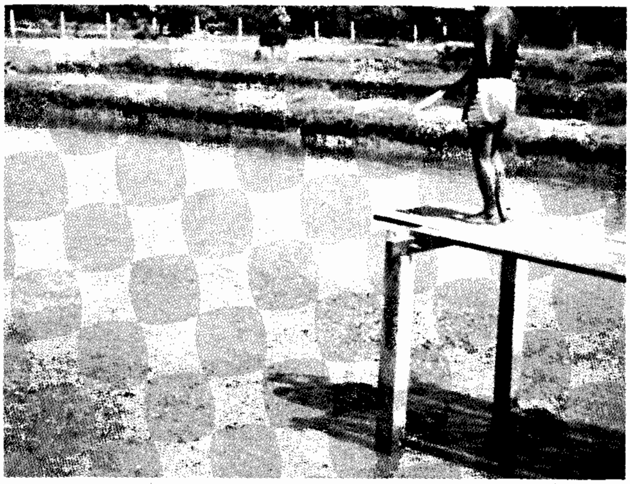
Boiled broken rice, another component of catfish feed.

Ground feed consists of boiled trashfish, broken rice and rice bran at an average mixture of 7:1:2.

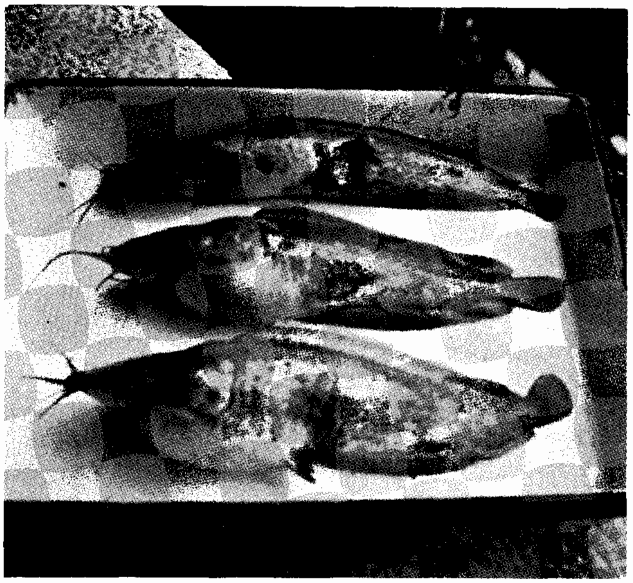


Manufactured feed is used to substitute trashfish. However, due to relatively high price, it is not widely accepted among catfish farmers.

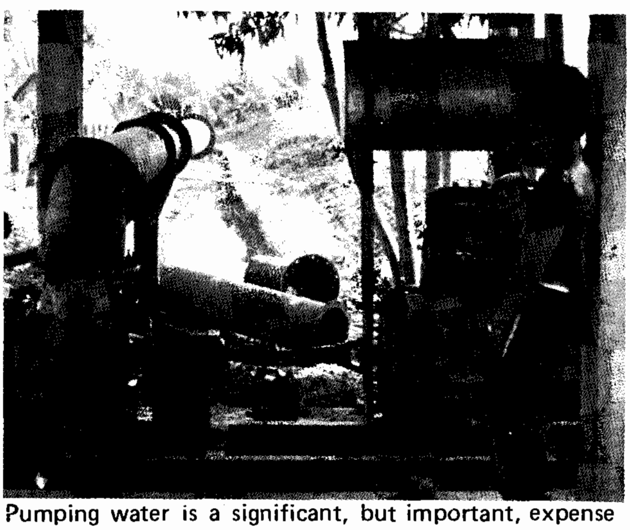
Manufactured feed for fry and fingerlings is also produced by several firms. Few farms were using it at the time of the study.



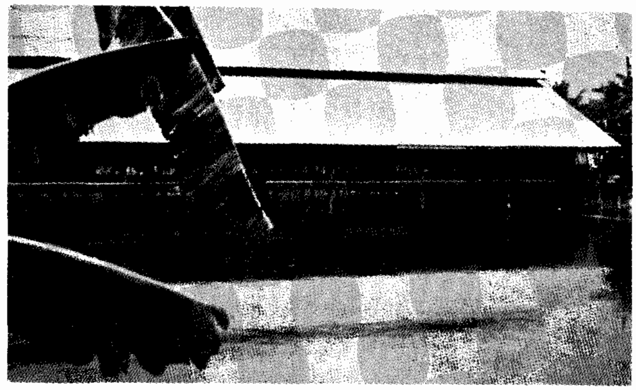
Feeding of catfish is usually done by hand.



Diseased fish are sent to the National Inland Fishery Institute (NIFI) for inspection.

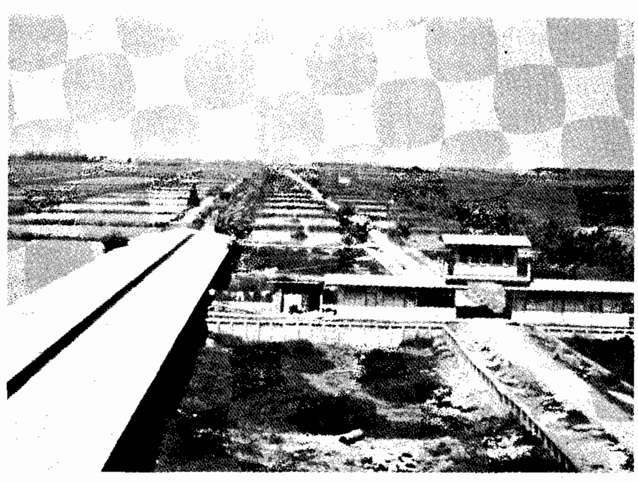


Pumping water is a significant, but important, expense item.

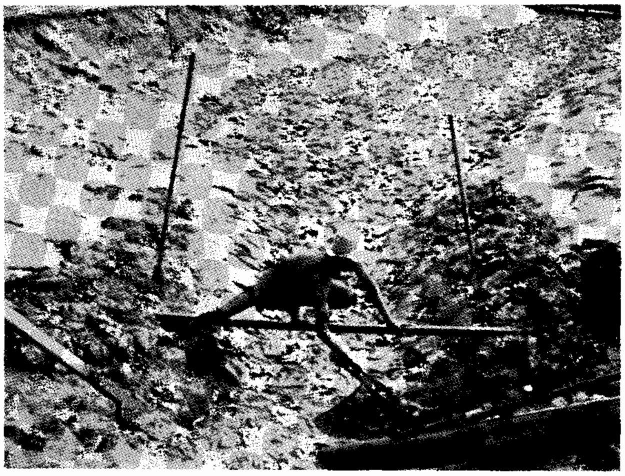


Integrated catfish farm with chicken house over the pond.

Pig sty and adjacent pond. Some large farms integrate pig and fish farming.



A large farm near Bangkok, which produces more than 20 species of fish.

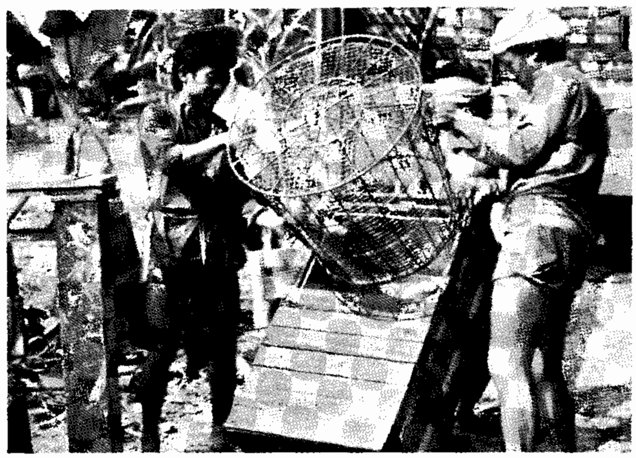


Harvesting: scooping fish from the pond after pumping out the water.

Harvesting by nets in large ponds. It requires several days to harvest by this method.

After harvesting, the fish are graded.

Weighing the catch: a basket contains about 65 kg of fish.



Fish are then transferred to a metal container (inside the timber frame) before adding water.

The fish are then transported alive to the market by truck.

Cost Structure and Profitability

YIELD AND INPUT USE

A summary comparison of yield and input use for the two locations, each representing a different type of culture, is given in Table 11. Farmers in Suphan Buri, having more experience, smaller pond area per farm and 2.5 times higher land value than farmers in Nakhon Nayok, practiced relatively intensive culture. Also, the superior water control in Suphan Buri allowed a longer culture period, resulting in more weight per harvested fish.

Farmers practicing intensive culture used feed with proportionately more protein and less carbohydrates than for extensive culture, but the food conversion ratio was 1.3 times higher (poorer), a result due only partially to the lower survival rate under intensive culture. Suphan Buri farmers used about 8 times more medicine/m^2 and 3 times more medicine/fingerling than Nakhon Nayok farmers, who used more fuel (2 and 6 times respectively) for water changes. The two types of culture did not differ substantially in the use of family labor per fingerling or in pond investment. However, intensive-culture farmers invested in building and equipment 2.5 times more per unit area than farmers practicing extensive culture.

In summary, Suphan Buri's more intensive culture gave a higher yield, but a lower survival rate and a poorer food conversion ratio.

COST STRUCTURE

Costs have been classified here into three broad categories: (i) 'cash' costs which vary with input use during the rearing period; (ii) fixed 'cash' costs which are independent of operation; and (iii) imputed or opportunity costs of owned inputs, which may be fixed or variable. This breakdown of costs was adopted in order to emphasize the distinction between outlays and imputed costs—or between that part of revenue which cannot be regarded as income to be consumed without impairing future operations—and that part of revenue that consists of payments to owned factors of production and hence constitutes farm income. The distinction between variable and fixed costs underlines the difference in decision rules between different planning horizons: in the short-run (say one season), fish farms would continue to operate as long as they cover their average variable costs; over the long-run operations would continue only if both variable and fixed costs are covered.

It was found, however, that variable cash costs dominate the cost structure of catfish farming to such a degree that all other costs are of relatively minor importance. Variable 'cash' costs accounted for over 93% of total costs, while other costs were about evenly divided between fixed 'cash' costs and imputed costs. As expected, the share of variable costs was higher under intensive culture: 94.1% (of total costs) in Suphan Buri compared to 90.6% in Nakhon Nayok (Table 12). These findings are in agreement with earlier studies on catfish farming in Thailand but they contrast with catfish farming elsewhere, as well as

Table 12. Cost structure of 40 farms in Suphan Buri and Nakhon Nayok, Thailand, 1979, based on Tables 13 and 14.

Cost item	% of subtotal cost Suphan Buri	Nakhon Nayok	Average	% of total cost Suphan Buri	Nakhon Nayok	Average
Variable costs						
Fingerlings	11.8	13.2	12.2	11.1	12.0	11.4
Feed	78.0	72.8	76.5	74.0	66.0	71.2
—trashfish	61.4	43.6	56.5	57.8	39.5	52.5
—rice bran	7.9	4.8	9.0	7.4	10.7	8.4
—broken rice	8.0	16.6	10.5	7.6	15.0	9.7
—artificial feed and vitamins	0.6	0.7	0.6	0.6	0.7	0.6
Fuel	1.7	5.0	2.7	1.6	4.6	2.5
Hired labor	1.1	2.4	1.5	1.0	2.1	1.4
Medicine, chemicals, etc.	2.1	0.1	0.6	0.5	0.9	0.6
Maintenance[1]	0.5	0.9	1.8	2.0	0.7	1.6
Interest on operating capital	4.8	4.8	4.8	4.5	4.3	4.4
Total	100.0	100.0	100.0	94.1	90.6	93.1
Fixed costs						
Depreciation of ponds	13.3	8.3	11.3	0.3	0.5	0.4
Depreciation of facilities[2]	61.1	63.6	62.0	1.6	3.4	2.1
Interest on debt	25.6	28.1	26.7	0.7	1.5	0.9
Total	100.0	100.0	100.0	2.6	5.3	3.4
Owned inputs						
Family labor	43.0	36.2	40.7	1.4	1.5	1.4
Interest on fixed capital	44.4	44.4	44.4	1.5	1.8	1.6
Land use	12.6	19.4	14.8	0.4	0.8	0.5
Total	100.0	100.0	100.0	3.3	4.1	3.5
Total costs	–	–	–	100.0	100.0	100.0

[1] Includes only maintenance of buildings, machinery and equipment; pond maintenance consisted mainly of labor costs.
[2] 'Facilities' include buildings, machinery and equipment (Table 13).

with other farming activities in Thailand. For instance, Adrian and McCoy (1972) report that operating costs for channel catfish farming in Alabama, U.S.A., accounted for only 80% of total costs. This difference is partly due to the different seed and feed requirements of the particular catfish species cultured there and partly due to the rather primitive structure of ponds and other farm facilities and equipment in Thailand. In the case of rice, usually the next best alternative to fish farming in Thailand, variable cash costs accounted for less than a fourth of total costs per unit of land area in 1975/76 (Division of Agricultural Economics 1977b). These differences underline the high sensitivity of catfish farming operations in Thailand to the variability of output and variable input prices. Moreover, unlike the cultivation of rice which is land and labor intensive, catfish farming makes little use of the farmer's owned factors of production (land and family labor), while it demands large amounts of cash or credit (as well as technical knowledge and management), often the farmers' most scarce resources. The variable costs of putting one rai (0.15 ha) of land to rice were less than 1,000 baht, while rearing catfish in a pond of the same size required on the average over 250,000 baht in variable costs (Table 17) of which over 75% was expended on feed alone. The rest was divided between seed (12%), interest on operating capital (5%), fuel (3%), maintenance (2%), and hired labor (1.5%). Expenses on medicine and chemicals were rather negligible (Table 12).

Farmers in Suphan Buri spent proportionately more on feed, particularly trashfish, and on maintenance while those in Nakhon Nayok spent proportionately more on fuel,

Table 13. Average capital and land investment (in baht) per square meter of pond area and per kilogram of fish produced from one crop at 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Items	Investment/m² of pond			Investment/kg of fish		
	Suphan Buri	Nakhon Nayok	Average	Suphan Buri	Nakhon Nayok	Average
Buildings, machinery and equipment						
Feed mixer and grinder	1.99	1.65	1.82	0.21	0.41	0.27
Motor and pump	3.17	2.16	2.65	0.33	0.53	0.40
Pan	0.07	0.06	0.06	0.01	0.02	0.01
Spade, hoe, container and net	0.14	0.43	0.29	0.02	0.11	0.04
Motorcycle and bicycle	0.69	0.85	0.77	0.07	0.21	0.12
Truck and car	12.12	2.23	6.98	1.27	0.55	1.04
Shelter and storage	7.17	1.84	4.40	0.75	0.45	0.66
Total building and equipment	25.35	9.22	16.97	2.66	2.28	2.54
Pond construction	5.53	5.18	5.35	0.58	1.28	0.80
Total capital investment	30.88	14.40	22.32	3.24	3.56	3.34
Land investment	11.00	7.82	9.35	1.15	7.93	1.40
Total investment	41.88	22.22	31.67	4.39	5.49	4.74

US$1 = 20.30 baht (1979).

Table 14. Average expected economic life and percentage use in catfish farming of capital assets at 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Items	Expected economic life (years)			Percentage catfish use		
	Suphan Buri	Nakhon Nayok	Average	Suphan Buri	Nakhon Nayok	Average
Equipment and facilities						
Feed mixer and grinder	11	11	11	73	74	73
Motor and pump	9	8	9	70	63	67
Shelter, storage and stove	11	10	11	57	83	63
Truck	11	9	10	47	18	40
Car	10	11	10	7	20	14
Motorcycle	11	11	11	30	20	24
Bicycle	10	9	10	20	44	34
Pan	4	6	5	74	69	72
Harvesting net	5	3	4	70	82	79
Container	1	1	1	80	64	72
Spade and hoe	2	4	3	83	69	76
Pond	10	10	10	100	100	100

hired labor and medicine. It is notable that in the extensive culture of Nakhon Nayok trashfish accounted for only 39.5% of total costs and broken rice for as much as 15% while in the intensive culture of Suphan Buri the proportions were 57.8% and 7.6% respectively.

Fixed costs, comprised of depreciation of ponds (11%), depreciation of facilities and equipment (62%) and interest on debt (27%), averaged a mere 3.4% of total cost, being higher under extensive culture as expected (Table 12). The average farm under each type of culture spent slightly less than 10,000 baht on fixed costs (Table 17). Capital investment was relatively low, 60,376 baht per farm, when compared to the annual operating cost of 269,770 baht per farm. Intensive culture was more capital intensive than average in terms of total capital expenditure, and even more so in terms of expenditure per unit of land area. Investment per square meter of pond area stocked and per kilogram of fish produced are shown in Table 13. The expected economic life and percentage use in catfish farming of capital assets are given in Table 14.

Table 15. Average cost in baht[1] per square meter of pond area and per kilogram of fish in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Cost item	Per square meter of pond area Suphan Buri	Nakhon Nayok	Average	Per kilogram of fish Suphan Buri	Nakhon Nayok	Average
Sample size	22	18		22	18	
Average pond area (m^2/farm)	2,361	3,125	2,705	2,361	3,125	2,705
Average yield (grams/m^2)	9,560	4,060	6,200	9,560	4,060	6,200
Variable costs (V)						
Fingerlings	17.69	7.08	12.17	1.85	1.74	1.82
Feed	116.67	39.06	76.32	12.21	9.62	11.39
Fuel and electricity	2.61	2.69	2.66	0.27	0.66	0.40
Hired labor	1.65	1.27	1.45	0.17	0.31	0.22
Medicine, chemicals, etc.	3.15	0.42	1.74	0.3	0.12	0.26
Maintenance[2]	0.74	0.51	0.62	0.08	0.13	0.09
Interest on operating capital	7.13	2.56	4.75	0.75	0.63	0.71
Total	149.64	53.65	99.73	15.66	13.21	14.81
(Standard deviation)[3]	(94.69)	(60.08)	(94.88)	(17.19)	(7.60)	(14.40)
Fixed costs (F)						
Depreciation of pond	0.55	0.26	0.41	0.06	0.06	0.06
Depreciation of facilities[4]	2.53	1.99	2.25	0.27	0.49	0.34
Interest on debt	1.06	0.88	0.97	0.11	0.22	0.15
Total	4.14	3.13	3.63	0.44	0.77	0.55
(Standard deviation)	(4.75)	(7.72)	(5.16)	(0.95)	(4.07)	(2.96)
Owned inputs (opportunity costs)						
Family labor (V')	0.66	0.47	0.56	0.07	0.12	0.09
Interest on fixed capital (F')	2.25	0.88	1.54	0.24	0.22	0.25
Land use (F')	2.32	1.08	1.68	0.25	0.27	0.26
Total	5.23	2.43	3.78	0.56	0.61	0.60
(Standard deviation)	(6.1)	(4.4)	(5.4)	(1.3)	(7.1)	(5.0)
Total costs	159.01	59.21	107.14	16.66	14.59	15.9
(Standard deviation)	(100.6)	(63.7)	(98.5)	(18.5)	(7.4)	(17.9)

[1]US$1 = 20.30 baht (1979).
[2]Includes only maintenance of buildings, machinery and equipment. Pond maintenance consisted mainly of labor costs.
[3]Standard deviations refer to the entries immediately above them.
[4]'Facilities' include buildings, machinery and equipment (see Table 14).
Notation: V and F refer respectively to variable and fixed costs which cannot be regarded as income to be consumed without impairing future operations. V' and F', on the other hand, refer respectively to variable and fixed costs which consist of payments to owned factors of production and hence constitute net family income.

The opportunity cost of owned inputs of land, family labor and fixed capital (i.e., what these factors could earn in their next best alternative) was relatively minor, accounting for only 3.5% of total costs. The average farm practicing extensive culture utilized owned inputs valued at 7,594 baht compared to 12,348 baht under intensive culture but the former was a higher percentage of corresponding total costs partly because of the use of relatively more land (Table 12). Total investment including land was 85,667 baht per farm, still only a fraction of the operating costs for a single crop (Table 17).

This total cost picture is translated into average terms, that is, per unit of pond area stocked and per unit of output produced, in Table 15. To farm one square meter of pond area under intensive culture required 149.64 baht in variable costs, 4.14 in fixed costs, and 5.23 in opportunity cost of inputs. The corresponding figures under extensive culture are 53.65 baht, 3.13 baht and 2.43 baht. In total, 159 baht/m^2 was spent under intensive culture to obtain an average yield of 9.56 kg/m^2 compared with only 59 baht/m^2 under

Table 16. Average revenues, costs and returns in baht[1] per square meter of pond area and per kilogram of fish produced from one crop at 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Cost and return item	Per square meter of pond area: Suphan Buri	Nakhon Nayok	Average	Per kilogram of fish: Suphan Buri	Nakhon Nayok	Average
Sample size	22	18		22	18	
Average pond area (m^2/farm)	2,361	3,125	2,705	2,361	3,125	2,705
Average yield (grams/m^2)	9,560	4,060	6,200	9,560	4,060	6,200
Gross revenues	185.51	79.93	130.62	19.41	19.69	19.50
(Standard deviation)	(120.2)	(72.0)	(95.6)	(3.7)	(3.2)	(3.4)
Costs						
Variable costs (V)	149.64	53.65	99.73	15.66	13.21	14.81
Fixed costs (F)	4.14	3.13	3.63	0.44	0.77	0.55
Opportunity costs, owned inputs	5.23	2.43	3.78	0.56	0.61	0.60
Total costs	159.01	59.21	107.14	16.66	14.59	15.96
(Standard deviation)[2]	(100.6)	(63.7)	(98.5)	(18.5)	(17.4)	(17.9)
Returns						
Operating profit[3]	35.87	26.28	30.89	3.75	6.48	4.69
Net income[4]	31.73	23.15	27.26	3.31	5.71	4.14
Return to capital and management	28.82	21.80	25.16	3.00	5.37	3.80
Net profit[5]	26.50	20.72	13.76	2.75	5.10	3.54
(Standard deviation)[5]	(99.0)	(35.8)	(71.1)	(19.4)	(17.6)	(18.4)

[1]US$1 = 20.30 baht (1979).
[2]Standard deviations refer to the entries immediately above them.
[3]Operating profit = gross revenues – variable costs (V).
[4]Net income ≡ return to owned inputs = operating profit – fixed costs (F).
[5]Net profit ≡ return to management = gross revenues – total costs.

extensive culture for a yield of 4.06 kg/m^2. This meant that with all costs taken into account it was cheaper on average to produce a kilogram of fish by extensive culture (14.59 baht/kg) than by intensive culture (16.66 baht/kg). In the cases of costs both per unit of pond area and per unit of output, dispersion around the mean was significant.

PROFITABILITY

There are various concepts of profitability depending on what costs are deducted from gross revenues. As shown in Table 16, the average farm in Suphan Buri had total receipts of 437,989 baht compared with 247,969 baht in Nakhon Nayok. On average, this meant, respectively, 185.51 baht and 79.93 baht/m^2 of pond area stocked and 19.41 baht and 19.69 baht/kg of fish produced. Since there was no significant difference in the price of fish obtained in the two locations or under the two different types of culture, virtually the entire difference in gross revenues can be explained by the difference in yield.

The first indicator of profitability is operating profit defined as gross revenues minus variable costs. Positive operating profit ensures continuation of operations in the short-run, i.e., as long as fixed assets cannot be liquidated without undue loss, or in the present case, as long as switching to another farming activity is not possible. The operating profit per farm was positive and not significantly different between the two locations. The average farm earned 84,689 baht or 19% of gross revenues in Suphan Buri and 82,125 baht or 33% of gross revenues in Nakhon Nayok. In terms of operating profit per unit of land area, the former was 1.4 times more profitable, while in terms of operating profit per unit of output

Table 17. Total revenues, costs and rates of return in baht[1] per farm in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Cost and return item	Suphan Buri	Nakhon Nayok	Average
Sample size	22	18	
Total pond area (m^2/farm)	2,361	3,125	2,705
Gross revenues	437,989	247,969	353,327
Costs			
Variable costs	353,300	167,656	269,770
Fixed costs	9,775	9,781	9,819
Opportunity costs of owned inputs	12,348	7,594	10,225
Total costs	375,423	185,031	289,814
Returns			
Operating profit[2]	84,689	82,125	83,557
Net farm income[3]	74,915	72,344	73,738
Return to land, capital and management	69,602	69,594	69,599
Return to capital and management	68,044	68,125	68,058
Net profit[4]	62,567	64,750	63,513
Investment			
Capital investment (CI)	72,907	45,000	60,376
Total investment (TI)	98,879	69,437	85,667
Rates of return (%)			
Rate of return to CI[5]	93.3	151.4	112.7
Rate of return to TI[6]	70.0	100.2	81.2
Ratio of net profits to variable costs (x 100)	17.7	38.6	23.5
Ratio of net profits to gross revenues (x 100)	14.3	26.1	18.0

[1]US$1 = 20.30 baht (1979).
[2]Operating profit = gross revenues — variable costs (V).
[3]Net farm income ≡ return to owned inputs = operating profit — fixed costs (F).
[4]Net profit ≡ return to management = gross revenues — total costs.
[5]Rate of return to capital investment = (return to capital and management/capital investment) x 100.
[6]Rate of return to total investment = (return to land, capital and management/total investment) x 100.

the latter was 1.7 times more profitable, reflecting the difference in intensity of culture (Table 16).

Another concept of profitability is that of net income defined as the return to owned factors of production, and calculated as operating profit net of fixed costs. The significance of this concept is that it can be consumed or saved without impairing the economic unit's ability to operate in the future. The net income in this case is again positive and in the neighborhood of 73,000 baht per farm. Much the same comparative picture as with operating profit holds between the two locations as a result of the relative insignificance of fixed costs.

Last, net profit or return to management can be calculated as gross revenues minus total costs. Net profit is the indicator of profitability and prospects of operation over the long-run. Non-negative net profit is a requirement for long-term viability of the operation. Again, we found that on the average net profit per farm is positive and in absolute amount not significantly different between the two types of culture or locations. The average farm in Suphan Buri earned a net profit of 62,507 baht or 14% of gross revenues while in Nakhon Nayok the corresponding profit figure was 64,750 baht or 26% (Table 17). The average farmer earned a net profit of 26.50 baht/m^2 of pond area stocked of 2.75 baht/kg of fish produced, while the latter earned 20.72 baht/m^2 or 5.10/kg of fish (Table 16). Thus, extensive culture was twice as profitable per unit of output but less profitable per unit of land. As to the deviation from the mean profit value, the dispersion was considerably larger in the case of intensive culture.

The average catfish farm in both locations earned a multiple of the average net farm income in the country, 10,500 baht in 1975 (Division of Agricultural Economics 1979). Moreover, catfish farming was at least as profitable as other investments. The average catfish farm earned 113% on capital investment (not including land) or 81% on total investment compared to the opportunity cost of capital (interest rate) which did not exceed 15% in 1979.

However, catfish farming is considerably more risky than other types of investment. While our data include both successful and unsuccessful farms, thus making some allowance for the risk element, it should also be taken into account that 1979 was a rather good year for catfish farming in Thailand. Even if we allow (arbitrarily) for a 50% probability of obtaining a profit less than the 1979 figure, catfish farming still appears, *on the average*, quite profitable. Since catfish culture uses relatively modest amounts of fixed capital in comparison to its operating capital requirements, an alternative index of its profitability is the ratio of net profits to variable costs which was as high as 23.5%, that is, in addition to a normal return on fixed capital, a 23.5% return on short-term (4-6 months) investments was obtained. Alternatively, net profits accounted for 18% of gross revenues, i.e., for every dollar received from the sale of fish 18 cents was net profit (Table 17).

Although there was little difference in the absolute value of net profits per farm between the two locations, Nakhon Nayok farmers earned a return on capital investment 1.6 times higher than Suphan Buri farmers because the former use a less capital-intensive culture method. When land is also taken into account, the return differential between the two locations is somewhat reduced because of the land-saving nature of intensive culture. However, it was not eliminated since land has a higher value in Suphan Buri. Moreover, the low variable-input use in the case of Nakhon Nayok meant lower operating capital per farm (despite the larger pond area) and hence a ratio of net profits to variable costs (38.6%) double that of Suphan Buri (17.7%).

SUMMARY OF COST AND PROFITABILITY FINDINGS

Our main findings on costs and profits in catfish farming in the two sampled provinces may be summarized as follows:

(1) Intensive culture gives a higher yield in terms of output per unit area but lower survival rate and worse feed conversion ratio.

(2) Farmers practicing intensive culture tend to use more medicine and less fuel for water changes, partly due to the better drainage system of ponds in Suphan Buri than in Nakhon Nayok. There is also a tendency under intensive culture to practice higher feeding rates per fingerling and to feed more protein and less carbohydrates than under extensive culture.

(3) Variable costs in general and feeding costs in particular dominate the cost structure of catfish farming. Under intensive culture, feeding costs account for three-fourths of total costs with trashfish being the most important feed item, accounting for 78% of feeding costs. Extensive culture is less feed-intensive; feed accounts for only two-thirds of total costs and trashfish for only 60% of feeding costs. Stocking costs constitute the next most important cost item, accounting for about 11% of total costs. By comparison expenses on labor, land and fixed assets are minor.

(4) As a corollary of the above cost structure, it may be said that under present technology and the prevailing economic conditions in Thailand, catfish farming does not fit the situation of the average Thai farmer, as it uses very little of the farmer's own factors of pro-

duction (land and family labor) and requires enormous amounts of operating (risk) capital—far beyond the capacity of the average farmer. Unless considerable credit becomes available, with due allowance for the uncertainties involved, there is little hope that catfish farming will expand significantly in the future.

(5) Catfish were produced 12% cheaper under extensive than intensive culture, and they were sold at about the same price. As a result, the profit margin in Nakhon Nayok was about 85% higher than in Suphan Buri. However, intensive culture had the highest net profit per unit of land area. Overall, because of the higher yield in Suphan Buri and the larger farm size in Nakhon Nayok, the total net profits per farm in the two locations were at about the same level. However, the highest rates of return to capital investment and operating capital were obtained under extensive culture.

In conclusion, extensive culture appears somewhat superior in that it economizes on scarce capital (both fixed and operating), uses more and cheaper land and produces catfish at the least cost. Both types of culture, however, appear to have provided the farmers, *on the average*, with excess profits over and above the opportunity cost of capital (normal return) in investments of comparable risk.

The Role of Farm Size and Experience

While catfish farming appears to be, on the average, profitable it would be appropriate to examine whether the reported average figures are representative of individual farms or merely the result of averaging profitable and unprofitable farms. We have already noted that the standard deviations in relation to the corresponding means are significantly higher in the case of profit than in the case of either cost or gross revenues (Table 15). This issue is discussed below.

Farm size, as measured by total pond area, might have an effect on yields, cost structure and profitability because of either differences in management or economies of scale. Similarly, farmers' experience in catfish farming is likely to be a significant factor in this new industry with its heavy requirements of technical knowledge and managerial ability.

THE ROLE OF FARM SIZE

The forty sampled farms were classified according to their total pond area under catfish into small (1,000 m^2 or less), medium (between 1,001 and 3,000 m^2) and large (over 3,000 m^2). The sample comprised 12 small, 15 medium and 13 large farms.[4] The average yield and input use by size of farm are given in Table 18. The highest average yield, almost 11 kg/m^2, was obtained in the large farms under intensive culture, which had the highest overall stocking rate, 193 fingerlings/m^2 and the second highest feeding rate, 0.30 kg/fingerling. Within this type of culture there was little difference between small and medium farms, with the former being marginally more 'productive.' Under extensive culture, small farms obtain the highest yield, 7 kg/m^2, the same as the small farms under intensive culture. By far the lowest yield, 2.4 kg/m^2, was that of the medium-sized ponds under extensive culture, which had the lowest stocking rate, 62 fingerlings/m^2 and lowest feeding rate, 0.11 kg/fingerling.

In general, high yields correspond to high stocking and feeding rates. Feeding rates appear to compensate, within limits, for low stocking rates, as can be seen from Table 19. The same yield is obtained from high stocking rates and low feeding rates as is obtained for lower stocking rates and higher feeding rates. This suggests the need for a rigorous study of input substitutability in aquaculture, a topic beyond our scope here.

In terms of feed composition there was a tendency among the high-yield farms to use proportionately more rice bran than among the low-yield farms such as the medium and large farms under extensive culture and medium farms under intensive culture. The last mentioned, in particular, used very little rice bran; 90% of the feed used by weight was

[4]One of the sampled farms from Suphan Buri was dropped from the economic analysis because of incomplete information.

Table 18. Farm size: average yield and input use in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Item	Suphan Buri Small	Suphan Buri Medium	Suphan Buri Large	Nakhon Nayok Small	Nakhon Nayok Medium	Nakhon Nayok Large
Sample size (farms)	7	8	7	5	7	6
Average farm size (m^2 of pond area)	626	1,618	4,946	692	1,749	6,757
Average yield (kg/m^2)	7.07	6.79	10.91	7.06	2.42	4.30
Stocking rate ($fingerlings/m^2$)	125.00	182.00	193.00	84.00	62.00	79.00
Feeding rate (kg/m^2/crop)	46.06	33.66	58.26	31.86	6.66	19.08
Feed/stocking ratio (kg/fingerling/crop)	0.28	0.19	0.30	0.38	0.11	0.24
Feed-mix: trashfish (% by weight)	73.60	89.70	78.03	78.23	76.93	58.28
rice bran (% by weight)	15.40	1.00	14.36	11.92	8.47	19.65
broken rice (% by weight)	11.00	9.30	7.59	9.85	14.58	22.08
Artificial feed ($baht/m^2$)	0.14	0.02	0.47	0.15	0.82	0.01
Conversion ratio (feed/yield)	6.51	4.96	5.35	4.51	2.76	4.44
Survival rate (%)	29.72	14.24	40.88	59.52	32.90	52.46
Medicine ($baht/m^2$)	10.95	1.30	2.58	0.85	0.52	0.30
Fuel use: ($liters/m^2$)	0.51	0.42	0.30	2.16	2.51	0.12
(liters/100 fingerlings)	0.31	0.23	0.15	2.56	4.03	0.15
(liters/100 kg feed)	1.11	1.26	0.51	6.78	37.65	0.64
Family labor ($man\text{-}hours/m^2$)	0.95	0.56	0.07	0.48	0.22	0.04
Pond investment ($baht/m^2$)	5.38	4.32	6.01	5.35	4.07	5.50
Investment in facilities ($baht/m^2$)	17.94	21.07	27.95	20.71	12.09	7.30
Culture period (months)	4.14	4.13	4.0	3.5	4.00	3.2
Cropping intensity (crops/year)	1.29	1.38	1.43	1.20	1.29	1.83
Farmers experience (years)	6.71	7.75	6.00	2.80	3.29	2.83

Table 19. Apparent substitutability between stocking and feeding rates.

Size/type of farm	Stocking rate ($fingerlings/m^2$)	Feeding rate (kg/fingerling/crop)	Yield (kg/m^2)
Medium/intensive	182	0.19	6.79
Small/intensive	125	0.28	7.07
Small/extensive	84	0.38	7.06

trashfish compared to only 58 to 78% by other size groups (Table 18). The medium-sized intensive farms had also the lowest survival rate, 14%, and among the intensive farms the best feed conversion ratio (apparently the high mortality occurred during the earlier stages of the culture period). The highest overall survival rate, 60%, was attained by small extensive farms and the best overall feed conversion ratio, 2.76 by medium-sized extensive farms. Small farms under each type of culture spent more on medicine per unit area than other size groups under the same type of culture. Moreover, small and medium-sized farms under extensive culture use proportionately more fuel for water changes than the remaining groups (Table 18).

Cost structure and profitability under intensive culture

Variable costs as a percentage of total costs were only slightly higher for large ponds, 95%, than for medium, 93%, and small farms, 92% (Table 20). However, the composition of variable costs differed considerably: large farms spent 82% of their variable costs on feed and only 8% on fry, while medium-sized farms spent only 60% on feed and 22% on fry,

Table 20. Farm size: average cost in baht[1] per square meter of pond area and per kilogram of fish in 22 catfish farms in Suphan Buri, Thailand, 1979.

Cost item	Per m² of pond area			Per kilogram of fish		
	Small[2]	Medium	Large	Small	Medium	Large
Sample size	7	8	7	7	8	7
Average pond area (m²/farm)	626	1,618	4,946	626	1,618	4,946
Average yield (kg/m²)	7.07	6.79	10.91	7.07	6.79	10.91
Variable costs (V)						
Fingerlings	22.28	24.95	14.39	3.15	3.67	1.32
Feed	104.46	69.69	132.04	14.77	11.73	12.11
Fuel	2.85	2.61	2.59	0.40	0.38	0.24
Hired labor	1.91	0.90	1.90	0.27	0.13	0.17
Medicine, chemicals, etc.	10.95	1.30	2.54	1.55	0.19	0.24
Maintenance[3]	3.48	0.22	0.59	0.49	0.03	0.25
Interest on operating capital	7.32	5.50	7.71	1.03	0.81	0.71
Total	153.67	115.41	161.93	21.72	16.98	14.85
(Standard deviation)[4]	(102.7)	(99.1)	(94.7)	(25.0)	(7.0)	(16.4)
Fixed costs (F)						
Depreciation of ponds	0.54	0.43	0.60	0.80	0.06	0.06
Depreciation of facilities[5]	3.55	2.71	2.33	0.50	0.40	0.21
Interest on debt	1.21	1.74	0.78	0.17	0.26	0.07
Total	5.30	4.88	3.71	0.75	0.72	3.34
(Standard deviation)	(5.9)	(5.6)	(1.2)	(1.4)	(0.7)	(0.2)
Owned inputs (opportunity costs)						
Family labor (V')	4.40	2.68	1.82	0.62	0.39	0.17
Interest on fixed capital (F')	1.75	1.90	2.55	0.25	0.28	0.23
Land use (F')	0.66	0.66	0.66	0.09	0.10	0.06
Total	6.81	5.24	5.03	0.91	0.77	0.46
(Standard deviation)	(10.0)	(1.6)	(3.71)	(2.1)	(0.8)	(0.6)
Total costs	165.78	125.53	170.67	23.43	18.47	15.65
(Standard deviation)	(114.4)	(101.1)	(74.2)	(27.3)	(7.4)	(16.8)

[1]US$1 = 20.30 baht (1979).
[2]'Small' ≡ less than 1,000 m²; 'medium' ≡ between 1,000 m² and 3,000 m²; 'large' ≡ more than 3,000 m².
[3]Includes only maintenance of buildings, machinery and equipment. Pond maintenance consisted mainly of labor costs.
[4]Standard deviations refer to the entries immediately above them.
[5]'Facilities' include buildings, machinery and equipment (Table 13).
Notation: V and F refer, respectively, to variable and fixed costs which cannot be regarded as income to be consumed without impairing future operations. V' and F', on the other hand, refer, respectively to variable and fixed costs which consist of payments to owned factors of production and hence constitute net family income.

reflecting differences in feeding rather than stocking rates. Small farms were somewhere in between. Average fixed costs both per unit of land and per unit of output were, as expected, highest for small ponds and lowest for large ponds. Total costs/m² of pond area were about equal between the large and small farms (in the range 166-171 baht), but significantly lower for medium-sized farms. Large farms produced catfish at the lowest cost, 15.65 baht/kg, followed by medium-sized farms, 18.47 baht/kg, with small farms being the costliest producers, 23.43 baht/kg. Thus, large farms produced catfish at 7.78 baht or 33% cheaper than small farms (Table 20).

Operating profit, net income and net profit were all negative for small farms and positive for large farms. Medium-sized farms had positive operating profit and negative net income and net profit. Under these conditions we would expect small farms to cease operating even in the short-run, medium farms to continue operating in the short-run but cease operations in the long-run, and large farms to continue operating in the short-run and

Table 21. Farm size: average revenues, cost and returns in baht[1] per square meter of pond area and per kilogram of fish in 22 catfish farms in Suphan Buri, Thailand, 1979.

Cost and return item	Per m^2 of pond area			Per kilogram of fish		
	Small[2]	Medium	Large	Small	Medium	Large
Sample size	7	8	7	7	8	7
Average pond area (m^2/farm)	626	1,618	4,946	626	1,618	4,946
Average yield (kg/m^2)	7.07	6.79	10.91	7.07	6.79	10.91
Gross revenues	135.33	117.66	217.22	19.14	17.33	19.92
(Standard deviation)	(96.2)	(70.5)	(111.8)	(2.3)	(3.4)	(5.5)
Costs						
Variable costs (V)	153.67	115.41	161.93	21.72	16.98	14.85
Fixed costs (F)	5.30	4.88	3.71	0.75	0.72	0.34
Opportunity costs of owned inputs	6.81	5.24	5.03	0.96	0.77	0.46
Total costs	165.78	125.53	170.67	23.43	18.47	15.65
(Standard deviation)[3]	(114.4)	(101.1)	(74.2)	(27.3)	(7.4)	(16.8)
Returns						
Operating profit[4]	−18.34	2.25	55.29	2.58	0.35	5.07
Net income[5]	−23.64	−2.63	51.58	−3.33	−0.37	4.43
Return to land, capital and management	−28.04	4.45	49.76	−3.95	−0.76	4.26
Return to capital and management	−28.70	−5.97	49.10	−4.04	−0.86	4.20
Net profit[6]	−30.45	−7.87	46.55	−4.29	−1.14	4.27
(Standard deviation)	(102.0)	(69.7)	(111.9)	(28.0)	(9.6)	(17.1)

[1] US$1 = 20.30 baht (1979).
[2] 'Small' ≡ less than 1,000 m^2; 'medium' ≡ between 1,000 m^2 and 3,000 m^2; 'large' ≡ more than 3,000 m^2.
[3] Standard deviations refer to the entries immediately above them.
[4] Operating profit = gross revenues – variable costs (V).
[5] Net income ≡ return to owned inputs = operating profit – fixed costs (F).
[6] Net profit ≡ return to management = gross revenues – total costs.

expand operations in the long-run. While all the farms were operating at the time of the survey, only 7 farms, mostly of large size, were planning to stay in catfish farming if the prevailing conditions of rising trashfish prices continue; 4 farms were uncertain, while the remaining 11 farms said they would be leaving the industry.

After all costs were taken into account, small farms in Suphan Buri lost on the average 30.45 baht/m^2 stocked or 4.29 baht/kg of fish sold; in total, they lost about 19,000 baht per farm or 20% of variable costs incurred. Medium-sized farms lost on the average 7.87 baht/m^2 or a total of 12,700 baht. This contrasts with large farms which earned on the average a net profit of 46.55/m^2 or a total of 230,000 baht from a single crop of catfish. The return to total investment (including land) for large farms was 110.4%; as much as 21.4% of all receipts from the sale of the crop were net profit over and above the normal return to capital and the payment of all other factors of production (Table 21).

Cost structure and profitability under extensive culture

As with intensive culture, variable costs as a proportion of total costs in extensive catfish culture are higher for larger ponds, 93%, than for small or medium, around 85%. In fact, this difference is larger under extensive culture because of the larger differences in the land area between large ponds and the medium and small categories.

In terms of variable cost composition, there were three important differences among the three size groups: (i) the cost of fry as a percentage of variable costs was considerably lower for small farms, 6%, than for other size groups, 14%; (ii) the cost of feed as a per-

Table 22. Farm size: average costs in baht[1] per square meter of pond area and per kilogram of fish in 18 catfish farms in Nakhon Nayok, Thailand, 1979.

Cost item	Per m^2 of pond area			Per kilogram of fish		
	Small[2]	Medium	Large	Small	Medium	Large
Sample size (farms)	5	7	6	5	7	6
Average pnd area (m^2/farm)	692	1,749	6,757	692	1,749	6,757
Average yield (kg/m^2)	7.06	2.42	4.30	7.06	2.42	4.30
Variable costs(V)						
Fingerlings	6.01	4.79	7.86	0.85	1.98	1.83
Feed	81.37	17.63	41.92	11.52	7.30	0.75
Fuel	7.02	8.13	0.68	0.99	3.37	0.16
Hired labor	5.70	0.73	1.05	0.81	0.30	0.25
Medicine, chemicals, etc.	1.14	0.68	0.37	0.16	0.29	0.09
Maintenance[3]	1.00	0.90	0.35	0.14	0.37	0.08
Interest on operating capital	5.11	1.64	2.61	0.72	0.68	0.61
Total	107.35	34.50	54.84	15.19	14.29	12.77
(Standard deviation)[4]	(75.17)	(30.37)	(61.71)	(7.05)	(8.35)	(6.21)
Fixed costs (F)						
Depreciation of pond	0.69	0.32	0.20	0.10	0.13	0.05
Depreciation of facilities[5]	5.06	2.52	1.57	0.72	1.04	0.36
Interest on debt	3.18	0.78	0.71	0.45	0.32	0.17
Total	8.93	3.62	2.48	1.27	1.49	0.58
(Standard deviation)	(8.58)	(1.48)	(2.07)	(2.81)	(5.94)	(1.81)
Owned inputs (opportunity costs)						
Family labor (V')	5.34	1.29	0.37	0.76	0.54	0.09
Interest on fixed capital (F')	2.03	1.21	0.96	0.29	0.50	0.22
Land use (F')	0.47	0.47	0.47	0.07	0.19	0.11
Total	7.84	2.97	1.80	1.12	1.12	0.42
(Standard deviation)	(4.8)	(1.9)	(0.8)	(6.6)	(9.9)	(1.7)
Total costs	124.12	41.09	59.12	17.58	16.96	13.77
(Standard deviation)	(76.0)	(30.3)	(0.7)	(14.3)	(23.6)	(7.1)

[1]US$1 = 20.30 baht (1979).
[2]'Small' ≡ less than 1,000 m^2; 'medium' ≡ between 1,000 m^2 and 3,000 m^2; 'large' ≡ more than 3,000 m^2.
[3]Includes only maintenance of buildings, machinery and equipment. Pond maintenance consisted mainly of labor costs.
[4]Standard deviations refer to the entries immediately above them.
[5]'Facilities' include buildings, machinery and equipment (Table 13).
Notation: V and F refer respectively to variable and fixed costs which cannot be regarded as income to be consumed without impairing future operations. V' and F', on the other hand, refer respectively to variable and fixed costs which consist of payments to own factors of production and hence constitute net family income.

centage of variable costs was lower for medium farms, 51%, than for other size groups, 76%; and (iii) there were considerable differences among the three groups in the share of fuel in variable costs, ranging from 1% for large farms, 7% for small farms, to 24% for medium farms.

When total costs per unit area were considered, small farms spent over three times the amount spent by medium farms and over twice that of large farms. This meant that small farms were the costliest producers per unit of output despite their considerably higher yield. A kilo of fish produced by small farms cost 17.58 baht compared to 16.96 baht by medium-sized farms and 13.77 baht by large farms. Both fixed and variable costs per unit of output decreased with the size of farm, suggesting the presence of economies of scale (Table 22).

Not only did large farms have the lowest unit cost they also obtained the highest unit price, 20.68, compared to only 16.97 baht by small farms and 16.17 by medium-sized

Table 23. Farm size: average revenues, costs and returns in baht[1] per square meter of pond area and per kilogram of fish in 18 catfish farms in Nakhon Nayok, Thailand, 1979.

Cost item	Per m² of pond area Small[2]	Medium	Large	Per kilogram of fish Small	Medium	Large
Sample size	5	7	6	5	7	6
Average pond area (m²/farm)	692	1,749	6,757	692	1,749	6,757
Average yield (kg/m²)	7.06	2.42	4.30	7.06	2.42	4.30
Gross revenues	119.87	39.04	88.87	16.97	16.37	20.68
(Standard deviation)	(77.5)	(39.1)	(71.1)	(2.2)	(3.1)	(3.4)
Costs						
Variable costs (V)	107.35	34.50	54.84	15.21	14.29	12.77
Fixed costs (F)	8.93	3.62	2.48	1.27	1.49	0.58
Opportunity costs of owned inputs	7.84	2.97	1.80	1.12	1.12	0.42
Total costs	124.12	41.09	59.12	17.58	16.96	13.77
(Standard deviation)[3]	(76.0)	(30.3)	(60.7)	(14.3)	(23.6)	(7.1)
Returns						
Operating profit[4]	12.52	4.54	34.03	1.78	1.88	7.91
Net income[5]	3.59	0.92	31.55	0.51	0.39	7.33
Return to land, capital and management	−1.75	−0.46	31.18	−0.25	−0.15	7.02
Return to capital and management	−2.22	−0.84	30.71	−0.32	−0.34	7.13
Net profit[6]	−4.25	−2.05	29.75	−0.61	−0.84	6.91
(Standard deviation)	(49.8)	(11.7)	(60.7)	(14.9)	(22.8)	(7.9)

[1]US$1 = 20.30 baht (1979).
[2]'Small' ≡ less than 1,000 m²; 'medium' ≡ between 1,000 m² and 3,000 m²; 'large' ≡ more than 3,000 m².
[3]Standard deviations refer to the entries immediately above them.
[4]Operating profit = gross revenues − variable costs (V).
[5]Net income ≡ return to owned inputs = operating profit − fixed costs (F).
[6]Net profit ≡ *return to management = gross revenues − total costs.*

farms as shown in Table 23. (Recall that the medium-sized group obtained the lowest price under intensive culture also). This price-cost situation meant that all but the large farms incurred losses or negative net profits. Large farms earned a net profit of 6.91 baht/kg of fish produced while small and medium farms have losses of 0.61 baht and 0.84 baht/kg of fish respectively. Large farms earned almost 30 baht/m² of pond area over and above the opportunity costs of all inputs used, while small and medium-sized farms earned 4.25 baht and 2.05 baht/m² below their respective opportunity costs (Table 23). This does not mean that small- and medium-scale farmers earned no income from fish farming or that they left the industry after this crop since both groups earned on the average positive net incomes (i.e., positive though not 'satisfactory' return to owned factors of production) and positive operating profit (i.e., they covered their variable costs and part of the fixed costs). While this was the average situation, it was apparent from the relatively high standard deviations that there were several farms that did not cover their operating costs and they were expected to cease operations even in the short-run. The most likely alternative to catfish farming is the culture of different fish, especially snakehead, which requires more or less the same inputs and has the advantage of being less vulnerable to the diseases prevalent in Thailand, though it requires a longer culture period.

Expressing cost structure and profitability in total quantities per farm reveals additional information, especially with regard to (i) total variable costs, which indicate the amount of operating capital or credit needed; (ii) net family income derived from catfish farming, which can be compared to income from other activities; (iii) total profits and losses; and (iv) rates of return on investment. Unlike intensive culture where total variable costs increase with

Table 24. Farm size: total revenues, costs and rates of return per farm in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Cost and return item	Suphan Buri Small[1]	Suphan Buri Medium	Suphan Buri Large	Nakhon Nayok Small	Nakhon Nayok Medium	Nakhon Nayok Large
Sample size (farms)	7	8	7	5	7	6
Average pond area (m^2/farm)	626	1,618	4,946	692	1,474	6,767
Gross revenues (baht)[2]	84,717	190,374	1,074,370	82,950	68,281	600,494
Costs (baht)						
Variable costs (V)	96,197	196,733	752,812	74,286	60,340	370,554
Fixed costs (F)	3,318	7,896	17,247	6,180	6,331	16,757
Opportunity costs of owned inputs	4,263	8,414	24,878	5,425	5,194	12,162
Total costs	103,778	203,107	843,985	85,891	71,866	399,474
Returns (baht)						
Operating profit[3]	–11,480	3,460	273,464	8,664	7,940	229,941
Net income[4]	–14,799	–4,255	255,115	1,484	1,609	213,183
Return to land, capital and management	–17,565	–8,591	245,618	–1,211	–804	210,683
Return to capital and management	–17,965	–9,659	242,848	–1,536	–1,469	207,507
Net profit[5]	–19,093	–12,733	230,236	–2,941	–3,585	201,021
Investment (baht)						
Capital investment (CI)	14,598	41,065	167,966	18,725	28,264	96,490
Total investment (TI)	21,484	58,863	222,372	24,137	41,941	139,329
Rates of return (%)						
Rate of return to CI[6]	–123.1	–8.9	144.6	–8.2	–5.2	239.9
Rate of return to TI[7]	–81.6	–14.6	110.4	–5.0	–1.9	151.2
Ratio of net profit to variable costs (x 100)	–19.8	–6.8	28.1	–4.0	–6.0	54.2
Ratio of net profit to gross revenues (x 100)	–22.5	–6.7	21.4	–3.5	–5.2	33.4

[1]'Small' ≡ less than 1,000 m^2; 'medium' ≡ between 1,000 and 3,000 m^2; 'large' ≡ more than 3,000 m^2.
[2]US$1 = 20.30 baht (1979).
[3]Operating profit = gross revenues — variable costs (V).
[4]Net farm income = operating profit — fixed costs (F).
[5]Net profit = gross revenues — total costs.
[6]Rate of return to investment = (return to capital and management/investment) x 100.
[7]Return to total investment = (return to land, capital and management/total investment) x 100.

size of farm, under extensive culture medium farms had the lowest variable costs, 60,340 baht compared to 74,286 baht by small farms and 370,554 baht by large farms. Although these figures are considerably lower than those under intensive culture they are still far beyond the funds and credit available to the average farmer. The operating capital requirements are particularly restrictive in the light of our finding that on the average only large farms with operating capital over 370,000 baht are successful (Table 24).

Small and medium-sized farms under extensive culture (unlike those under intensive culture) earned positive net incomes of 2,484 baht and 1,609 baht per crop, or 2,980 baht on 2,076 baht per year, respectively, based on 1.20 crops per year for small farms and 1.29 crops per year for medium-sized farms. These incomes, however, are very low by comparison to what the farmers' resources could earn from their next best alternative employment—even in 1975 the average less-than-2-rai farm earned 5,733 baht (Division of Agricultural Economics 1979). In contrast, recall our finding that large catfish farms earn on the average 213,183 baht, a multiple of the national average farming income of 10,500 baht per household in 1975.

In terms of net profit, small and medium farms lost on the average 2,941 baht and

Table 25. Farmers' experience: average yield and input use in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Item	Suphan Buri Inexperienced	Suphan Buri Experienced	Nakhon Nayok Inexperienced	Nakhon Nayok Experienced
Sample size	12	10	10	8
Average farm size (m^2 of pond area)	2,736	1,911	1,982	4,553
Average yield (kg/m^2)	7.41	13.25	1.54	5.43
Stocking rate (fingerlings/m^2)	194.00	177.00	45.00	93.00
Feeding rate (kg/m^2/crop)	51.69	50.28	7.08	22.66
Feed/stocking ratio (kg/fingerling)	0.27	0.28	0.16	0.24
Feed-mix: trashfish (% by weight)	78.07	77.44	68.23	61.04
rice bran (% by weight)	14.79	13.16	12.16	18.88
broken rice (% by weight)	7.14	9.40	19.61	20.08
Artificial feed (baht/m^2)	0.25	0.23	–	0.43
Conversion ratio (feed/yield)	6.98	3.80	4.60	4.17
Survival rate (%)	24.49	50.77	31.94	54.02
Medicine (baht/m^2)	2.87	3.12	0.43	0.35
Fuel use (liters/m^2)	0.38	0.29	0.23	1.06
(liters/100 fingerlings)	0.20	0.17	0.51	1.14
(liters/100 kg feed)	0.74	0.59	3.20	4.68
Family labor (man-hours/m^2)	0.22	0.34	0.24	0.03
Pond investment (baht/m^2)	6.98	3.03	4.84	5.38
Investment in facilities (baht/m^2)	28.96	18.24	13.27	7.02
Culture period (months)	4.33	3.80	3.35	3.88
Cropping intensity (crops/year)	1.33	1.40	1.10	2.13
Farmers' experience (years)	3.92	10.40	1.20	4.75

3,588 baht, respectively, and hence had a negative rate of return to capital invested; large farms earned over 200,000 baht per farm or a rate of return of about 150% on total investment (Table 24).

THE ROLE OF EXPERIENCE

Experience of catfish farmers was rated differently in the two provinces. The average experience was 6.9 years in Suphan Buri and 2.9 years in Nakhon Nayok. In both cases, the farmers were classified into two categories—inexperienced (less than average) and experienced (more than average).

A different cut-off point for experience between the two locations is warranted by the different type and intensity of culture in the two locations (the minor overlap in stocking rates notwithstanding). In both our appraisal and that of industry representatives, the type of culture practiced in Suphan Buri requires far more experience (over five years according to inveterate farmers) than the type of culture practiced in Nakhon Nayok, where 3 years was considered adequate. A host of related factors explains this: stocking rates, feeding rates, prevalence of disease, learning by action versus learning from the experience of others.

There were 10 experienced farmers in Suphan Buri and 8 in Nakhon Nayok; inexperienced farmers numbered 12 and 10, respectively. Among the 12 experienced farmers in Suphan Buri, 7 had been in catfish culture for 10 to 15 years. In Nakhon Nayok only 1 farm had been in the business for over 5 years. Among the inexperienced farmers there was only 1 newcomer in Suphan Buri and 6 in Nakhon Nayok.

Experience of farmer and size of farm were correlated for extensive culture. However, under intensive culture, the reverse was the case. As shown in Table 25, experienced farmers achieved higher yields; the difference was considerably larger under extensive culture.

Table 26. Farmers' experience: average cost in baht[1] per square meter of pond area and per kilogram of fish in 22 catfish farms in Suphan Buri, Thailand, 1979.

Cost item	Per m^2 of pond area		Per kg of fish	
	Inexperienced[2]	Experienced	Inexperienced	Experienced
Sample size	12	10	12	10
Average pond area (m^2/farm)	2,736	1,911	2,736	1,911
Average yield (kg/m^2)	7.41	13.25	7.41	13.25
Variable costs (V)				
Fingerlings	14.98	22.33	2.02	1.67
Feed	112.20	124.36	15.14	9.39
Fuel	2.56	2.72	0.35	0.21
Hired labor	1.28	2.28	0.17	0.17
Medicine, chemicals, etc.	2.87	3.45	0.40	0.27
Maintenance[3]	0.62	0.95	0.08	0.07
Interest on operating capital	6.73	7.80	0.91	0.59
Total	141.34	163.89	19.07	12.37
(Standard deviation)[4]	(76.5)	(113.5)	(11.7)	(22.9)
Fixed costs (F)				
Depreciation of ponds	0.64	0.41	0.09	0.03
Depreciation of facilities[5]	2.68	2.28	0.36	0.17
Interest on debt	0.45	2.11	0.06	0.16
Total	3.77	4.80	0.51	0.36
(Standard deviation)	(4.4)	(5.4)	(0.8)	(1.1)
Owned inputs (opportunity costs)				
Family labor (V')	2.65	1.56	0.36	0.12
Interest on fixed capital (F')	2.70	1.60	0.36	0.12
Land use (F')	0.66	0.66	0.09	0.05
Total	6.01	3.82	0.81	0.29
(Standard deviation)	(7.8)	(2.8)	(1.5)	(1.1)
Total costs	151.12	172.51	20.39	13.02
(Standard deviation)	(84.1)	(116.1)	(3.4)	(24.7)

[1]US$1 = 20.30 baht (1979).
[2]'Inexperienced' ≡ a farmer with less than average experience (6.9 years) in catfish farming; 'experienced' ≡ a farmer with more than average experience (6.9 years) in catfish farming.
[3]Includes only maintenance of buildings, machinery and equipment. Pond maintenance consisted mainly of labor costs.
[4]Standard deviations refer to the entries immediately above them.
[5]'Facilities' include buildings, machinery and equipment (see Table 13).

Experienced farmers of Nakhon Nayok (extensive) stocked twice as many fingerlings as inexperienced farmers, used three times as much feed per unit area and obtained over three-and-a-half times the yield of the latter. In contrast, experienced farmers in Suphan Buri (intensive) stocked fewer fingerlings and obtained almost 80% more yield per unit area than inexperienced farmers with the same feeding rate.

There was little difference in the composition of feed on the basis of experience except that experienced farmers under extensive culture used less trashfish (61% by weight) and more rice bran (19%) than inexperienced farmers (68% and 12%, respectively). Experienced farmers in both locations achieved over 50% survival compared to 24% and 32% by inexperienced farmers in Suphan Buri and Nakhon Nayok, respectively. Experienced farmers had better feed conversion ratios and their capital investments were less. Yet they averaged more crops per year. In particular, inexperienced farmers in Nakhon Nayok cultured on the average only 1.10 crops per year, compared to 2.13 crops by experienced farmers (Table 25).

Table 27. Farmers' experience: average cost in baht[1] per square meter of pond area and per kilogram of fish in 18 catfish farms in Nakhon Nayok, Thailand, 1979.

Cost item	Per m^2 of pond area		Per kg of fish	
	Inexperienced[2]	Experienced	Inexperienced	Experienced
Sample size	10	8	10	8
Average pond area (m^2/farm)	1,983	4,553	1,993	4,553
Average yield (kg/m^2)	1.54	5.43	1.54	5.43
Variable costs (V)				
Fingerlings	3.28	9.15	2.13	1.69
Feed	17.69	50.69	11.48	9.34
Fuel	1.14	3.54	0.74	0.65
Hired labor	0.53	1.67	0.35	0.31
Medicine, chemicals, etc.	0.54	0.44	0.35	0.09
Maintenance[3]	0.17	0.70	0.11	0.13
Interest on operating capital	1.17	3.31	0.76	0.61
Total	24.52	69.50	15.92	12.82
(Standard deviation)[4]	(37.0)	(73.7)	(7.9)	(6.4)
Fixed costs (F)				
Depreciation of ponds	0.34	0.21	0.22	0.04
Depreciation of facilities[5]	2.32	1.81	1.51	0.33
Interest on debt	1.16	0.73	0.75	0.13
Total	3.82	2.75	2.48	0.50
(Standard deviation)	(3.9)	(7.8)	(5.0)	(1.2)
Owned inputs (opportunity costs)				
Family labor (V')	1.28	0.66	0.83	0.12
Interest on fixed capital (F')	1.36	0.93	0.88	0.17
Land use (F')	0.47	0.47	0.31	0.09
Total	3.11	2.06	2.02	0.38
(Standard deviation)	(4.2)	(4.8)	(8.8)	(0.6)
Total costs	31.45	74.31	20.42	13.70
(Standard deviation)	(40.4)	(78.6)	(38.7)	(6.8)

[1]US$1 = 20.30 baht (1979).
[2]'Inexperienced' ≡ a farmer with less than average experience (2.9 years) in catfish farming; 'experienced' ≡ a farmer with more than average experience (2.9 years) in catfish farming.
[3]Includes only maintenance of buildings, machinery and equipment. Pond maintenance consisted mainly of labor costs.
[4]Standard deviations refer to the entries immediately above them.
[5]'Facilities' include buildings, machinery and equipment (see Table 13).

There was little difference in cost structure between experienced and inexperienced farmers. Variable costs dominated total costs (94 to 95%)[5] and feed costs dominated variable costs (72-79%). It is worth noting, however, that inexperienced farmers used more family labor. Catfish were produced 32 to 36% cheaper by experienced farmers. Cost of a kilo of fish produced by the latter in either location was below 14 baht compared to over 20 baht by inexperienced farmers (Tables 26 and 27).

Farms owned and operated by experienced farmers were clearly more profitable than those owned and operated by inexperienced farmers, regardless of the type of culture. The gap between the two groups was wider under extensive culture because of the correlation between experience and farm size (Tables 28 and 29). While on the average both groups earned positive operating profits (allowing operations to continue over the short-run), inexperienced farmers in Nakhon Nayok earned negative net incomes and negative net profits.

[5]With the exception of inexperienced farmers in Nakhon Nayok (78%).

Table 28. Farmers' experience: average revenues, costs and returns in baht[1] per square meter of pond area and per kilogram of fish in 22 catfish farms in Suphan Buri, Thailand, 1979.

Cost and return item	Per m^2 of pond area		Per kg of fish	
	Inexperienced[2]	Experienced	Inexperienced	Experienced
Sample size	12	10	12	10
Average pond area (m^2/farm)	2,736	1,911	2,736	1,911
Average yield (kg/m^2)	7.41	13.25	7.41	13.25
Gross revenues	155.28	237.45	20.95	17.93
(Standard deviation)	(80.9)	(118.3)	(3.5)	(2.0)
Costs				
Variable costs (V)	141.34	163.89	19.07	12.37
Fixed costs (F)	3.77	4.80	0.51	0.36
Opportunity costs of owned inputs	6.01	3.82	0.81	0.29
Total costs	151.12	172.51	20.39	13.02
(Standard deviation)[3]	(84.1)	(116.1)	(13.4)	(24.7)
Returns				
Operating profit[4]	13.94	73.56	1.88	5.56
Net income[5]	10.17	68.76	1.37	5.20
Return to land, capital and management	7.52	67.20	1.01	5.08
Return to capital and management	6.86	66.54	0.92	5.03
Net profit[6]	4.16	64.96	0.56	5.01
(Standard deviation)	(86.7)	(121.1)	(14.8)	(25.3)

[1]US$1 = 20.30 baht (1979).
[2]'Inexperienced' ≡ a farmer with less than average experience (6.9 years) in catfish farming; 'experienced' ≡ a farmer with more than average experience (6.9 years) in catfish farming.
[3]Standard deviations refer to the entries immediately above them.
[4]Operating profit = gross revenues – variable costs (V).
[5]Net income ≡ return to owned input = operating profit – fixed costs (F).
[6]Net profit ≡ return to management = gross revenues – total costs.

They lost on the average 4.73 baht/m^2 of pond area or 3.08 baht/kg of fish produced. In contrast, experienced farmers, also using extensive culture, earned a net profit of 34.59 baht/m^2 or 6.36 baht/kg of fish (Table 29). In the case of intensive culture, the gap was somewhat reduced by the fact that several inexperienced farmers had large ponds and profited both by economies of scale and ability to obtain higher prices for their output. Inexperienced farmers earned on the average a net profit of 4.16 baht/m^2 of pond area and 0.56 baht/kg of fish, compared with 64.96 baht/m^2 and 5.01 baht/kg by experienced farmers (Table 28).

In Table 30, we compare total profitability per farm between the two groups of farmers. There were significant, but not striking differences in either gross revenues or total costs between experienced and inexperienced farmers in Suphan Buri, since both groups included small, medium and large farms. Farms operated by experienced farmers had somewhat higher gross revenues, despite the lower unit price they obtained, and considerably lower costs than inexperienced farmers, resulting in wide profit differential between the two groups of farmers. Experienced farmers in Suphan Buri averaged a net profit of 124,000 baht, compared to only 11,382 baht by inexperienced farmers. The rates of return to total investment (including land) were 208% and 17%, respectively.

The revenue, cost and profit differentials between the two groups were more striking in Nakhon Nayok where size and experience were correlated. Experienced farmers outlayed 6.5 times as much per farm and earned more than 9 times as much as inexperienced farmers. Whereas, the former earned a net profit of 157,488 baht per farm or 178% on investment, the latter incurred a loss of 9,380 baht per farm. In other words, experienced farmers

Table 29. Farmers' experience: average revenues, costs and returns in baht[1] per square meter of pond area and per kilogram of fish in 18 catfish farms in Nakhon Nayok, Thailand, 1979.

Cost and return item	Per m² of pond area Inexperienced[2]	Experienced	Per kg of fish Inexperienced	Experienced
Sample size	10	8	10	8
Average pond area (m²/farm)	1,983	4,553	1,983	4,553
Average yield (kg/m²)	1.54	5.43	1.54	5.43
Gross revenues	26.72	108.90	17.34	20.06
(Standard deviation)	(45.9)	(70.2)	(3.0)	(2.7)
Costs				
Variable costs (V)	24.52	69.50	15.92	12.82
Fixed costs (F)	3.82	2.75	2.48	0.50
Opportunity costs of owned inputs	3.11	2.06	2.02	0.38
Total costs	31.45	74.31	20.42	13.70
(Standard deviation)[3]	(40.4)	(78.6)	(20.7)	(6.8)
Returns				
Operating profit[4]	2.20	39.40	1.42	7.24
Net income[5]	–1.62	36.65	–1.06	6.74
Return to land, capital and management	–2.90	35.99	–1.89	6.62
Return to capital and management	–3.37	35.52	–2.20	6.53
Net profit[6]	–4.73	34.59	–3.08	6.36
(Standard deviation)	(14.8)	(46.6)	(20.1)	(0.8)

[1]US$1 = 20.30 baht (1979).
[2]'Inexperienced' ≡ a farmer with less than average experience (2.9 years) in catfish farming; 'experienced' ≡ a farmer with more than average experience (2.9 years) in catfish farming.
[3]Standard deviations refer to the entries immediately above them.
[4]Operating profit = gross revenues – variable costs (V).
[5]Net farm income = operating profit – fixed costs (F).
[6]Net profit = gross revenues – total costs.

earned a 31.8% net profit over gross revenues while inexperienced farmers incurred a net loss of 17.7% (Table 30).

CONCLUSIONS ON FARM SIZE AND EXPERIENCE

In the preceding chapter we found that catfish farming was on the average a very profitable economic activity, regardless of the intensity of culture. Catfish farmers averaged a net profit of over 60,000 baht from a single 4-month crop or 80% on capital invested in 1979, a relatively high rate of return in comparison to the opportunity cost of capital (15 to 22%) at the time. From those findings one might have concluded, as several past studies did from similar findings, that catfish culture is a very lucrative farming activity which can be easily promoted among Thai farmers. However, the relatively large standard deviations from these averages, as well as reports of catfish farmers going out of business or switching to other crops, prompted us to investigate here the possibility that the high returns found were the result of averaging very high returns by a few successful farms and losses by others. Upon breaking down the sample according to farm size and experience, we found this to be the case.

124,000 to 230,236 baht, while small farms or inexperienced farmers incurred losses of between 9,300 and 19,093 baht. Relatively large farms operated by inexperienced farmers had a moderate profit, 11,382 baht. A successful farm was typically one of large size, owned

Table 30. Farmers' experience: total revenues, costs and rates of return in baht[1] per farm in 40 catfish farms in Suphan Buri and Nakhon Nayok, Thailand, 1979.

Cost and return item	Suphan Buri Inexperienced[2]	Suphan Buri Experienced	Nakhon Nayok Inexperienced	Nakhon Nayok Experienced
Sample size	12	10	10	8
Average pond area (m^2/farm)	2,736	1,911	1,983	4,553
Gross revenues	424,846	453,767	52,986	495,822
Costs				
Variable costs (V)	386,706	313,194	48,623	6,434
Fixed costs (F)	10,315	9,173	7,575	12,521
Opportunity costs of owned inputs	16,443	7,300	6,167	9,379
Total costs	413,346	329,667	62,365	338,334
Returns				
Operating profit[3]	38,140	140,573	4,363	179,388
Net farm income[4]	27,825	131,400	–3,212	166,867
Return to land, capital and management	20,575	128,419	–5,751	163,862
Return to capital and management	18,769	127,158	–6,683	161,723
Net profit[5]	11,382	124,100	–9,380	157,488
Investment				
Capital investment (CI)	98,332	40,647	35,912	56,457
Total investment (TI)	119,728	61,668	51,419	92,062
Rates of return (%)				
Rate of return to CI[6]	19.1	320.0	–16.6	286.5
Rate of return to TI[7]	17.2	208.2	–10.8	178.0
Ratio of net profit to variable costs (x 100)	2.9	39.6	–19.3	49.8
Ratio of net profit to gross revenues (x 100)	2.7	27.3	–17.7	31.8

[1]US$1 = 20.30 baht (1979).
[2]'Inexperienced' ≡ a farmer with less than average experience; 'experienced' ≡ a farmer with more than average experience. Average experience was 6.9 years in Suphan Buri and 2.9 years in Nakhon Nayok.
[3]Operating profit = gross revenues – variable costs (V).
[4]Net farm income = operating profit – fixed costs (F).
[5]Net profit = gross revenues – total costs.
[6]Rate of return to capital investment = (return to capital and management/capital investment) x 100.
[7]Rate of return to total investment = (return to land, capital and management/return to total investment) x 100.

and operated by an experienced farmer. Of the 22 Suphan Buri farms in the sample, 5 large farms with over 5 years of experience were very successful, earning net profits in excess of 160,000 baht from a single 4-month crop, while 11 farms, either small-to-medium or inexperienced had losses ranging between 13,000 baht and 470,000 baht. Of the remaining 6 farms, mostly of medium size and of considerable experience, 5 earned moderate profits and 1 broke even.

The implication of these findings is that a certain scale of operation and level of knowledge are required for a successful operation. Large-scale farmers are more likely to be full-time fish farmers or at least to be engaged in fish-farming-related activities which afford them information and knowledge usually unavailable to small farmers. A large-scale farmer is more likely to be able to take risks and sustain losses until he acquires the necessary experience for a successful operation. As a corollary, he has more room for experimentation and innovation than the small farmer. Easier accessibility of credit and economies of scale in the purchase of inputs and sale of output are added advantages for the large-scale farmer.

Availability of land, however, is not the main constraint limiting the size of a catfish farm. The binding factor is rather the availability of funds or credit to finance the variable costs of a larger operation and sustain early losses which might be correspondingly large.

A second binding constraint is the availability of the technical knowledge and skills required, and ability of the average farmer to stay in business until he discovers the right formula through trial and error and accumulated experience.

Farmers have been experimenting with many input combinations in their attempts to improve yields and reduce costs. The yield among the surveyed farmers ranged between 0.1 kg/m^2 and 20.3 kg/m^2. This raises the question as to what factors can account for these wide variations. Are farmers obtaining different yields because they are using different levels of input or because of varying efficiency in combining these inputs? Are farmers using inputs at profit-maximizing levels by ensuring that the last unit of input yields as much revenue as it costs or are they price-inefficient?

Some of these issues have already been addressed superficially. A more rigorous analysis follows.

Production Technology and Efficiency

Four questions relating to technology and efficiency are relevant to this study: First, of the many inputs used by catfish farmers, which are most significant in explaining variations in yield among farmers? Alternatively, what is the quantitative response of yield to a marginal increase of each input while holding all other inputs constant? Second, are there increasing returns to scale in the sense that output more than doubles when the level of all inputs is doubled? Third, how significant is the role of such factors as experience and farm size which, being fixed at any given point, cannot be bought on the market at least in the short-run? Alternatively, are there significant differences in technical efficiency among farmers with different levels of experience or with different size of farm? Last, are farmers price-efficient in the sense of using input levels dictated by the relative prices and productivities of the inputs. A number of other interesting issues were raised in the Introduction to this report, such as the degree of substitutability and interaction among inputs. These will not be addressed as they require a different, more complex analytical framework than the one adopted here.

ANALYTICAL FRAMEWORK: THE COBB-DOUGLAS PRODUCTION FUNCTION

An analytical device, the production function, is often used to answer such questions as those raised above. A production function is a relationship between inputs and output. It gives the maximum output obtainable with given quantities of inputs or the minimum amounts of various inputs necessary to produce a given level of output. In the case of catfish farming we have expressed the function as follows:

$$Y = F(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) \quad (1)$$

where Y : yield in kg/m^2 of pond area
X_1 : number of stocked fingerlings/m^2
X_2 : quantity of trashfish used in kg/m^2
X_3 : quantity of broken rice used in kg/m^2
X_4 : quantity of rice bran in kg/m^2
X_5 : amount of fuel in kg/m^2 as a proxy variable for water quality
X_6 : chemicals and medication in baht/m^2
X_7 : labor in man-days/m^2
X_8 : building, machinery and equipment in baht/m^2

A commonly used algebraic form of the production function (1) is the Cobb-Douglas function, which has some useful and convenient properties: it is linear in the logarithms of the variables; the estimated coefficients on the inputs give the corresponding output elasticities; and the sum of these coefficients indicates the returns to scale. The production function specified above, when put in Cobb-Douglas form, is as follows:

$$Y = AX_1^{b_1} X_2^{b_2} X_3^{b_3} \ldots . X_8^{b_8} \tag{2}$$

where A is a constant term and b_i is the 'transformation' parameter of the level of input X_i into Y. When put in logarithmic form (2) becomes:

$$\ell n\, Y = \ell n\, A + b_1\, \ell n\, X_1 + b_2\, \ell n\, X_2 + \ldots . b_8\, \ell n\, X_8 \tag{3}$$

where ℓn indicates natural logarithms.

The marginal product (MP_i) of an input (X_i) indicates the change in output that results from a marginal change in this input while holding all other inputs constant. It is obtained by taking the partial derivative of the production (4) with respect to the input:

$$MP_i \equiv \frac{\partial Y}{\partial X_i} = b_i \frac{Y}{X_i} \tag{4}$$

For $0 < b_i < 1$, MP_i is positive and declining with an increase in X_i and rising with an increase in other factors.

The production elasticity of an input indicates the percentage change in the quantity of output resulting from a percentage change in the input. It is obtained by logarithmic differentiation of the production function with respect to the input:

$$\epsilon_{YX_i} \equiv \frac{\partial\, \ell n\, y}{\partial\, \ell n X_i} = b_i \tag{5}$$

Thus, the production elasticities of the various inputs are constant and directly obtainable from the production function.

Similarly, the extent of economies of scale, i.e., the percentage increase in output due to a percentage increase of all inputs simultaneously, is conveniently obtainable as the sum of the estimated input coefficients:

$$\lambda = \sum_{i=1}^{n=8} b_i \tag{6}$$

If $\lambda > 1$, increasing returns to scale prevail, i.e., output increases by a larger percentage than the increase of all inputs; if $\lambda = 1$, constant returns to scale prevail; and if $\lambda < 1$, decreasing returns to scale prevail.

In the previous chapter considerable differences in yields (and profits) between small and medium farms on the one hand, and large farms on the other, were reported. Moreover, experienced farmers had higher yields (and profits) than newcomers. It would be useful to study the role of experience and farm size more rigorously in the framework of the specified production function. We do this by introducing dummy variables into the production function to distinguish between the three size groups and two experience groups defined earlier. The two locations are also distinguished by a dummy variable. Thus, equation (3) becomes:

$$\ell n\, Y = b_0 + b_1\, \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 + a_1 D_1 + a_2 D_2 + a_3 D_3 + a_4 D_4 \qquad (7)$$

where $b_0 = \ell n\, A$

D_1 = 1 if farm is small ($\leqslant$ 1,000 m^2);
= 0 if farm is medium (1,001 to 3,000 m^2) or large (> 3,000 m^2);
D_2 = 1 if farm is large;
= 0 if farm is medium or small;
D_3 = 1 if farmer has more than the average number of years of experience (6.9 for Suphan Buri and 2.9 for Nakhon Nayok);
= 0 if farmer has less than average number of years of experience;
D_4 = 1 if farm is located in Nakhon Nayok;
= 0 if farm is located in Suphan Buri.

After estimating the coefficients of equation (7) we can derive 12 production functions which will differ only in their intercept if all the dummy variables are significant. If only the farm size and experience turn out to be significant, we may distinguish 6 different production functions according to their intercepts:

for small farms with inexperienced farmers:

$$\ell n\, Y = (b_0 + a_1) + b_1\, \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 \qquad (8)$$

for small farms with experienced farmers:

$$\ell n\, Y = (b_0 + a_1 + a_3) + b_i\, \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 \qquad (9)$$

for medium-sized farms with inexperienced farmers:

$$\ell n\, Y = b_0 + b_1\, \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 \qquad (10)$$

for medium-sized farms with experienced farmers:

$$\ell n\, Y = (b_0 + a_3) + b_i \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 \qquad (11)$$

for large farms with inexperienced farmers:

$$\ell n\, Y = (b_0 + a_2) + b_1\, \ell n\, X_1 + \ldots + b_8\, \ell n\, X_8 \qquad (12)$$

and for large farms with experienced farmers:

$$\ell n\, Y = (b_0 + a_2 + a_3) + b_1\, \ell n\, X_1 + \ldots + \ell n\, X_8 \qquad (13)$$

Note that if the location dummy is also significant, a_4 should be added to the intercept of Nakhon Nayok farms, in which case we will have a total of 12 groups of farms. The relative magnitudes of these intercepts give a measure of the relative technical efficiency of farms with different location, size and level of experience: the higher the intercept the more productive the farm. Since the rest of the parameters of the production function remain the same among farms, a given percentage increase in any input will increase output by the same proportion. This will mean a different absolute amount for each size and experience group depending on its intercept.

Finally, the concept of price efficiency in input use is introduced. Farmers have different levels of fixed inputs (e.g., farm size and location) and face certain prices of variable inputs. Farmers are price-efficient if they use each variable input to the extent that the added return from the last unit yields as much value as it would have done in the next best alternative use. Under competitive conditions, the inputs' value in alternative use (their opportunity costs) are approximated by their market prices. The condition for price efficient behavior, therefore, is one of equality between the value of the marginal product (the added return) and the price of each variable input:

$$VMP_i \equiv P \cdot MP_i = P_i \tag{14}$$

where P is the price of output. This condition may be rewritten as

$$VMP_i/P_i = 1 \tag{15}$$

If $VMP_i/P_i > 1$ input i should be increased;
if $VMP_i/P_i = 1$ input i is used efficiently; and (16)
if $VMP_i/P_i < 1$ input i should be decreased.

In the case of the Cobb-Douglas production function, condition (15) becomes

$$b_i \frac{P\,Y}{P_i X_i} = 1 \tag{17}$$

EMPIRICAL FINDINGS: ELASTICITIES, RETURNS TO SCALE AND EFFICIENCY

Four regression models were constructed, to compensate for the low number of degrees of freedom resulting from the relatively small sample size, 40 farms. Equation (3) with appropriate stochastic specification (error term) was econometrically estimated using the ordinary least squares technique and observations from the 40 surveyed catfish farms. The results are reported as the first regression (R1) in Table 31. Of the eight explanatory variables used only four, namely fingerlings,trashfish, fuel and family labor were statistically significant at the 95% confidence level. This model could explain 70% of the variation in yield. Fingerlings were the most powerful explanatory variable, followed by trashfish, the feed component.

In order to improve the explanatory power of the overall model, as well as to investigate the role of farm size and experience, we carried out a second regression (R2), which involved the four significant explanatory variables of R1 plus three dummy variables, two for farm size and one for experience. The percentage of variation in yield explained by the new regression plane rose from 70% to 74% as indicated by the new coefficients of determination (R^2). The coefficient of family labor ceases to be statistically significant as does that on the dummy variable distinguishing between small and medium farms. The implication of the latter is that on the basis of our data there were no substantial differences in productivity between small and medium-sized farms (Table 31).

In contrast, the coefficient on the dummy variable distinguishing between large and

Table 31. Production coefficients and related statistics for a sample of 40 catfish farms in Thailand, 1979.

Variables		R 1 Coefficient	t-ratio	R 2 Coefficient	t-ratio	R 3 Coefficient	t-ratio	R 4 Coefficient	t-ratio
Constant		−0.765		−1.194		−0.728		−1.134	
Fingerlings	X_1	0.484**	(4.234)	0.445**	(3.995)	0.364**	(3.315)	0.394**	(3.724)
Trashfish	X_2	0.226**	(3.088)	0.223**	(3.107)	0.145*	(1.942)	0.128*	(1.684)
Broken rice	X_3	...	...	–	–	–	–	0.169**	(2.439)
Rice bran	X_4	...	...	–	–	–	–	...	...
Fuel	X_5	0.116*	(1.747)	0.187*	(2.917)	0.180**	(3.003)	0.135*	(2.299)
Treatment	X_6	...	...	–	–	0.162**	(2.392)	0.203**	(3.018)
Labor	X_7	0.071*	(1.914)	...	–	–	–	...	...
Equipment	X_8	...	...	–	–	–	–	...	...
Small farms	D_1	–	–	...	...	...	...	...	...
Large farms	D_2	–	–	0.441*	(2.094)	0.502**	(2.521)	0.519**	(2.802)
Experience	D_3	–	–	0.461**	(2.418)	0.644**	(3.314)	0.727**	(3.966)
Location	D_4	–	–	–	–	–	–	0.264	(1.104)
Sum of bj coefficient, λ		0.897		0.855		0.851		1.029	
R^2 adjusted		0.701		0.743		0.775		0.806	
F-ratio		23.851		22.722		22.518		20.422	

– Inclusion of the variable in the regression was not attempted.
... Inclusion of the variable in the regression was attempted but as it turned out to be statistically insignificant at the 95% level it was dropped and the regression rerun yielding the reported results.
* Statistically significant at the 95% confidence level.
** Statistically significant at the 99% confidence level.

medium-sized farms was positive and statistically significant at the 95% level, indicating that there was a difference in productivity between large farms on the one hand and medium and small farms on the other. Similarly, the coefficient on the dummy variable representing experience indicates a significant difference in productivity between experienced and inexperienced farmers. As discussed earlier, a relative measure of technical efficiency may be obtained by comparing the intercepts of the production functions of the significantly different groups. In our case, four groups may be distinguished:

(i) small and medium-sized farms, inexperienced farmers, −1.194;
(ii) small and medium-sized farms, experienced farmers, −0.733;
(iii) large farms and inexperienced farmers, −0.753;
(iv) large farms and experienced farmers, −0.292.

Thus, technically the least efficient are the small and medium farms operated by inexperienced farmers while the most efficient are large farms operated by experienced farmers. Small farms with experienced operators are about as efficient as large farms with less experienced operators. These results confirm our previous findings on the role of farm size and experience (p. 35-48).

As decreasing returns to scale (λ = 0.855) were found to exist even after the introduction of experience and farm size, we examined the possibility that variables which appeared insignificant in R1 might be significant under the new specification. Indeed, medication and broken rice turned out to be significant at the 99% confidence level. The introduction of treatment alone is reported first (R3) because of its impact on the significance of the trashfish coefficient. There is a rather high correlation between these two variables but exclusion of one results in mispecification of the model. Apart from being the most important input in terms of costs, trashfish was the second most significant variable after fingerlings when introduced in a stepwise regression.

Treatment, on the other hand, contributed significantly to the overall explanatory power of the model, apart from being itself statistically significant. Similar comments apply to broken rice, which was the second most important component of feed, being correlated with trashfish (some farmers use them in fixed proportions). Its inclusion in R4 caused a further decline in the absolute magnitude of the coefficient for trashfish and its statistical significance as an explanatory variable of yield variations, while increasing the overall explanatory power of the model. In fact, regression R4 is based on equation (8) with the statistically insignificant coefficients omitted.

The coefficients on equipment, labor and rice bran, a third component of feed used for adhesiveness as well as for nutrition, were not significantly different from zero at any reasonable confidence level and were dropped from the final model reported in R4. Location was retained, despite its apparent statistical insignificance, because of its role in distinguishing between the two locations in the sample and its contribution to the overall explanatory power of the model.

Regression R4 should be considered as the final and most satisfactory result. Over 80% of the variation in yields has been explained by the five variable inputs and three fixed factors included in the model. The five variable inputs were stocking material, two types of feed, fuel for water changes, and medical treatment. The fixed factors were farm size, experience and location. The estimated production elasticity of stocking material (fingerlings) indicates that 10% increase in the number of fingerlings stocked per square meter while holding all other inputs constant will increase yield by 3.94%. A similar 10% increase in trashfish will increase yields by 1.28%, in broken rice by 1.69%, in fuel by 1.35%, in treatment by 2.03%. The sum of all production elasticities was equal to 1.029 indicating that a simultaneous 10% increase in all inputs would increase output by 10.29% which implies modestly increasing returns to scale. Again, small and medium farms operated by inexperienced farmers were technically the least efficient (intercept −1.134), while large farms operated by experienced farmers were technically the most efficient (intercept +0.112).

In order to study price efficiency, the marginal products (MP_i) of four main inputs (fingerlings, trashfish, broken rice and fuel) were calculated at the geometric means. These marginal products were then multiplied by the output price to obtain the value of the marginal products (VMP_i). These values were then compared with the corresponding average prices of these inputs (P_i) according to the criteria set out in the set equations and inequalities (16) above. The results are reported in Table 32. Any value of VMP_i/P_i significantly different from unity implies that the input is used inefficiently. All inputs except, perhaps, medication, were found to be used inefficiently. Too many fingerlings were stocked per unit area and too much trashfish was used for feed under the prevailing input-output prices. In contrast, broken rice for feed and fuel for water change were used in quantities considerably below the optimal levels for profit maximization. Thus, profits would increase if the farmers were to lower stocking rates and change the composition of feed towards less trashfish and more broken rice. Additional increases in profit could be expected from an increase in the quantity of fuel used, which would lead, presumably, to improved water quality. In fact, better water quality would result also from the other changes necessary to improve efficiency, particularly from the lower stocking density and the substitution of part of the trashfish by broken rice. Considering that farmers face a capital constraint, it might not be possible for them to increase the use of fuel and broken rice, unless they economize on their scarce capital by reducing the excessive use of fry and trashfish as our findings suggest.

CONCLUSIONS ON INPUT USE

A number of important results have been obtained in this analysis. The most significant

Table 32. Marginal products, input prices and price efficiency in 40 catfish farms in Suphan Buri, Thailand, 1979.

Regression (based on Table 31)	Estimate of	Fingerlings X_1	Trashfish X_2	Broken rice X_3	Fuel X_5	Medication X_6
	MP_i	0.022	0.090	–	2.52	–
	VMP_i	0.423	1.755	–	44.63	–
R_1	P_i	0.936	2.350	–	4.75	–
	VMP_i/P_i	0.452	0.747	–	9.40	–
	Input use	decrease	decrease	–	increase	–
	MP_i	0.020	0.089	–	4.09	–
	VMP_i	0.385	1.730	–	49.70	–
R_2	P_i	0.936	2.350	–	4.75	–
	VMP_i/P_i	0.411	0.736	–	16.78	–
	Input use	decrease	decrease	–	increase	–
	MP_i	0.017	0.051	0.982	2.95	0.840
	VMP_i	0.341	0.996	19.120	57.54	0.840
R_4	P_i	0.936	2.350	3.000	4.75	1.000
	VMP_i/P_i	0.364	0.424	6.373	12.11	0.840
	Input use	decrease	decrease	increase	increase	decrease

MP_i = marginal product of input i.
VMP_i = value of marginal product of input i (MP_i x price of output).
P_i = price of input i.

inputs in catfish culture are fingerlings, trashfish, broken rice, fuel and treatment. At current input combinations, yield is most responsive to stocking rates: a 10% increase in the number of fingerlings yields to a 4% increase in yields. The response of the yield to increases in trashfish is rather weak; larger increments in output can be obtained by increases in broken rice, medication and fuel. In terms of profitability, however *both* the stocking rate and the use of trashfish should be lower while the use of broken rice and treatment should increase. Farmers presumably would be interested in higher profits while society may be interested in higher yields. It is necessary to find ways to reconcile this potential conflict of interests. A conflict may arise if there exist market failures, such as limited competition, and externalities which are beyond the scope of the present study.

Another area of possible conflict between what is privately profitable and what is socially desirable is that only large-scale farmers with substantial capital and skills are successful catfish farmers. If society is interested only in increased production at the lowest cost to the consumer, large-scale farming should be promoted. If, on the other hand, development of additional sources of employment and income for small-scale farmers is the objective, ways must be found to make catfish farming less risky by providing credit and technical assistance to the small farmers.

Summary and Policy Implications

The present study has focussed on four aspects of catfish farming in Thailand: farming practices, costs and returns, production technology and price efficiency. The role of intensity of culture, of farm size, and of experience in determining yield and profit was also explored. The main findings may be summarized as follows:

In the Central Plain of Thailand, stocking rates of catfish seed, though widely variable, were unusually high in comparison with the culture of other species. The most important component of feed was trashfish, which, despite its rising price and polluting effects, remains far more popular than artificial feed. The optimum feed-mix was determined by its 'stickiness' and the optimum feeding rate by observation of consumption. Diseases are more common in catfish than other cultured species because of high stocking densities and use of decayed trashfish. Most farmers treated diseases with terramycin and oxytetracycline and parasites with formalin. The culture period was about 3 to 4 months. Most farmers financed their operations through loans from either banks or middlemen.

There was little difference in cost structure between intensive and extensive culture as defined by stocking rate of ponds. Variable costs accounted for over 93% of total costs. Feed alone accounted for over 70% of total costs, and fry for about 11%. Despite a much lower yield, extensive culture produced catfish at lower average cost than intensive culture. Despite a higher cost per kilogram and a slightly lower price, intensive-culture farms earned a higher profit per unit of land area than those practicing extensive culture because of the farmers' higher yields. As expected, intensive farms appear to maximize the return to land while extensive farms maximize the return to capital. On the average, catfish farming was very profitable, yielding an average profit of over 60,000 baht per farm for a 4-month culture period and a return to capital at least five times its opportunity cost, regardless of the type of culture.

However, after stratifying the sample by farm size and farmers' experience, it was found that average figures were misleading because of considerable deviations from the mean value. While large-scale, experienced farmers earned enormous profits, small-scale and inexperienced farmers incurred considerable losses.

The estimation of the production technology of catfish culture in Thailand indicated that the main factors explaining variation in yield among farmers were seed, feed (especially trashfish and broken rice) and fuel consumption as a proxy for water quality. Again large-scale and experienced farmers were technically more efficient than small-scale and inexperienced farmers. There was no significant difference in technical efficiency between intensive and extensive culture. Returns to scale were nearly constant throughout. Up to 80% of the total variation in yield was explained; the rest could be attributed to biological and environmental factors which were not included in this study because of measurement difficulties.

Although increasing the stocking and feeding rates would increase yield considerably, profitability would decline as the use of seed and feed (trashfish) is already at inefficiently high levels when relative prices are considered. To increase profitability the use of broken rice and fuel should be increased and that of trashfish and fry decreased to the point where the value of their marginal contributions equals their unit cost.

Our findings point to the need for new feed formulas with due consideration of their productivity, side effects and relative prices and for new means to control disease effectively. The farmers should be provided with a spectrum of alternative input combinations so that they have flexibility to alter their input mix as relative prices change.

The higher technical efficiency of large-scale and experienced farmers points to the importance of scale economies, credit availability and extension. Few small-scale farmers can afford to stay in business until they acquire the necessary experience through trial and error. Given the economies of scale and social benefits from experimentation, the government should promote research in experimental farms and extension. Expansion in a high risk-high return activity can take place easier through a reduction of risk than through an increase of a highly uncertain return. Moreover, a minimum scale of operations appears to be necessary for success.

The price inefficiency in input use suggests that some farmers can turn their losses into profits and others increase their profits by simply changing their input combination according to relative prices, which at present dictate lower stocking densities, better water quality and some substitution of broken rice for trashfish. However, given the rapidity with which economic conditions change, any particular input combination recommended by the present or any other study would soon become obsolete. What is needed is a spectrum of input combinations under alternative sets of relative prices. This is a fertile area for collaborative biological and economic research and for a two-way extension service between the farmers and the scientists.

With regard to government policy towards catfish farmers, the government should assist farmers, especially those with small farms and little experience, to overcome the problems of high operating capital, insufficient knowledge and high risk arising from the spread of catfish diseases. Appropriate short-term credit schemes and practical research and effective extension on the problems of disease, feed-mix and water management are necessary if catfish farming is to recover from its present depressed situation and expand to realize its full potential in Thailand. It is encouraging that the National Inland Fisheries Institute of the Department of Fisheries is presently conducting research on catfish diseases, feed improvement and water quality. It is hoped that successful results obtained in laboratories and experimental farms will soon be made available in a form suitable for the benefit of the farmers.

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Appendix Tables

Appendix Table 1. Quantity and value of catfish production from the fishery and culture, Thailand, 1974-1979.

Unit: tons, *million* baht

Year	Fishery Quantity	Fishery Value	Culture Quantity	Culture Value	Total Quantity	Total Value
1974	24,937	338.4	10,105	144.6	34,505	483.0
1975	18,136	271.0	6,655	78.6	24,791	349.6
1976	13,598	244.6	6,116	70.8	19,714	315.4
1977	12,073	255.5	7,029	126.5	19,102	388.0
1978	14,896	253.9	7,602	118.6	22,498	472.5
1979	17,208	365.4	4,246	90.1	21,454	455.5

Source: Department of Fisheries, Ministry of Agriculture and Cooperatives, "Fisheries Record of Thailand" 1974, 1976 and 1979 and "Freshwater Fishery Fishfarm Production" 1979. Bangkok.

Appendix Table 2. Changes over time in the structure of the catfish farming industry in Suphan Buri, Thailand, 1967-78.

	1967	1973	1976	1978
No. of farms	45	468	76	79
No. of ponds	54	123	288	291
Ponds per farm	1.2	2.4	3.8	3.7
Average pond size m^2	306	441	1,194	1,306
Total pond area	16,506	495,646	343,788	383,158

Source: National Inland Fisheries Institute, Suphan *Buri* Annual *Report* 1978.

Appendix Table 3. Average monthly wholesale price (baht/kg) of catfish in local markets, Thailand, 1967-1980.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1967	9.35	9.10	9.05	9.12	9.46	10.07	10.56	10.86	10.87	10.46	10.32	10.58	9.98
1968	10.46	10.49	10.71	11.30	11.25	11.05	11.26	10.67	10.88	10.95	10.62	10.62	10.81
1969	12.21	11.11	11.42	11.88	11.62	11.63	12.05	12.02	10.85	10.47	10.77	10.93	11.33
1970	10.85	10.58	10.45	10.62	10.89	10.92	10.91	20.36	10.02	9.08	8.88	9.13	10.22
1971	9.06	9.35	9.70	9.87	10.33	10.49	10.25	10.22	10.12	10.19	10.62	10.72	10.08
1972	7.06	8.40	8.15	8.31	8.37	7.46	7.29	7.92	8.56	7.70	7.45	8.52	7.89
1973	9.12	9.89	9.82	10.01	10.85	11.98	12.08	12.59	12.77	9.67	11.47	11.46	10.97
1974	11.95	12.22	12.88	13.87	14.19	15.75	14.69	15.11	15.49	15.97	14.89	13.87	14.24
1975	17.20	17.56	17.70	18.37	18.34	18.26	20.16	19.00	17.37	15.84	15.98	17.08	17.74
1976	16.52	16.30	16.51	17.16	17.29	18.22	17.17	18.38	17.50	17.11	16.51	17.63	17.19
1977	17.13	17.05	17.13	18.91	20.36	19.65	19.85	19.69	19.81	19.87	20.04	21.07	19.21
1978	19.91	18.62	19.83	18.39	19.99	21.30	21.49	20.09	18.57	17.49	19.21	19.59	19.58
1979	17.29	18.20	18.05	18.92	19.49	18.87	19.01	22.62	21.48	20.99	21.54	22.62	19.92
1980	25.64	23.82	29.92	26.33	29.88	31.53	37.49	31.08	27.28	32.91	30.31	28.30	29.54
Average 1967-80	13.84	13.76	14.38	14.50	15.16	15.51	16.02	15.76	15.12	14.91	14.93	15.15	14.92

Source: Division of Agricultural Economics, Ministry of Agriculture and Cooperatives.