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BIOECONOMIC ANALYSIS OF COMMERCIAL POND CULTURING OF THE STRIPED CATFISH *Pangasianodon hypophthalmus* IN THE MEKONG DELTA, VIETNAM

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Key words: striped catfish (*Pangasianodon hypophthalmus*), production cost, profitability, multivariate statistical analysis.

ABSTRACT

An analysis of costs and returns for striped catfish grow-out pond culturing in the Mekong Delta, Vietnam taking into consideration the factor of geographical location, was conducted. The geographical location not only had an influence on the cost but also the profitability of the enterprise. Multivariate statistical analysis showed a decline in the operating costs and benefits, depending on the location, being highest in middle stream ponds, less in upstream ponds and finally lowest in downstream ponds. However, the earning power of downstream ponds was highest, in terms of profitability associated with fingerlings, feed and energy. Cobb Douglas production function analysis revealed that net revenue earned from increasing the scale of production would increase if feed cost input rose, but whereas net revenue would decrease with an increase of input medication costs. The statistic results also showed that the size of fingerlings from middle stream ponds (1.83 cm high), the stocking density from upstream ponds (47.17 fingerlings /m^2), and the weight of fish harvested from downstream ponds (0.86 kg/fish) are suitable for farming. Various levels of government could propagate suitable policies and put in place infrastructure to encourage farmers to use electricity for fuel instead of petroleum, to apply Global GAP (global agricultural practices) standards in production activities, to improve the competitive capacity of domestic feed processing companies, to expand fry nursery areas at downstream sites, and to increase fish prices through awareness campaigns designed to increase global demand.

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I. INTRODUCTION

Striped catfish culturing has been practiced in Vietnam's Mekong Delta since the 1960's. Traditionally, wild fry have been harvested from the Mekong River. Commercial culturing has been popularized since the successful development of artificial fry production techniques in 1996 and the development of the fry hatchery sector in 1998 (Le and Le, 2010). The sale of cultured striped catfish has made a significant contribution to the production of aquatic products for export. In 2010, production in the Mekong Delta was 1,141,000 tons, accounting for 42.15% of total aquaculture products produced by Vietnam (MARD, 2010), products were shipped to 140 countries (VASEP, 2011) and the industry provided approximately 180,000 jobs (NACA, 2010).

Despite being able to create a competitive advantage and overcome bottlenecks, catfish farming has often proved unsustainable because the balance between supply and demand in this sector seldom remains stable. The industry has also been harmed by negative publicity (Bush, 2011; FAO Globefish, 2011). Farmers have not been able to predict the profitability of their products and are almost entirely dependent on the purchasing price offered by processors and exporters (Belton et al., 2011).

Farmers profited more from the culturing of striped catfish in 2007-2008, due to low production costs and favorable market conditions (Le and Le, 2010). However, the industry was impacted by the world financial crisis in 2009. The farm-gate price of catfish fell to only VND 16,000/kg (USD 0.89/kg) in 2009 while production costs excluding capital investment costs were approximately VND 15,000/kg (USD 0.83/kg) (FAO, 2011). In addition, since early 2011, some operating costs, including petrol, feed, seed and labor expenses have sharply increased. With production costs at about VND 20,000/kg (USD 1.02/kg), excluding fixed costs and expenses needed to acquire the necessary certifications required by importing countries, many farmers lack the capital to continue farming. Consequently, by 2011, 40% of the farming areas in the Delta had been abandoned (CL-FISH, 2011).

It should also be noted that geographical location has an impact on striped catfish production costs. For example, fingerling costs are usually higher at downstream sites than upstream sites because the downstream sites are farther away from the fry hatcheries (Phan et al., 2009). In addition, upstream and middle stream sites normally suffer from annual flooding during the rainy season when fish can escape and epidemic disease has significantly reduced the income of fish farmers (Truong et al., 2009). This flooding can also cause erosion of aquaculture systems at upstream and middle stream sites so that fish ponds have to be located on higher ground and built more solidly that is necessary at downstream sites (MARD, 2006). Taken overall, more efficient management is necessary to maximize profit. It is hoped that a systematic analysis of costs and returns can provide suggestions for improvement in farm management.

Nguyen et al. (2007) studied the economics of using three different categories of feed for striped catfish culturing including: (i) manufactured pelleted feed; (ii) a combination of manufactured pelleted and farm-made feeds; and (iii) farm-made feed. They showed that feed costs accounted for the highest percentage of total production cost, an average of 86.51% for all categories. Farmers using manufactured feed had higher production costs with lower net returns and profitability (144,338 USD, 14,193 USD and 0.13, respectively) than farmers using a combination of manufactured and farm-made feeds (111,614 USD, 20,085 USD and 0.22, respectively) or farm-made feed (66,658 USD, 21,515 USD and 0.31, respectively). Clearly, it is more economically efficient to use farm-made feed than manufactured feed. Despite this, many farmers switched to manufactured feeds due to an increase in the price and shortage in the supply of raw materials, as well as concerns with environmental pollution and quality of the fish by the international market. The authors applied the Cobb-Douglas production function to identify the effects of independent variables on the yield of striped catfish. The results show that an increase in the total quantity of feed associated with the stocking density had a significant impact on the yield of catfish cultured in ponds in the Mekong Delta. Le and Le (2010) found that the yield, production cost and net returns of ponds in inland provinces were 369.7 tones/ha/crop, 256,394 USD and 49,085 USD, respectively, higher than ponds in coastal provinces, which was 280.9 tons/ha/crop, 196,867 USD and 36,697 USD, respectively. The feed and fingerling costs were attributed to large percentages, 75% and 12% of the operating costs. The results of multiple regression analysis suggest that productivity was optimal when: (1) the water depth was 4-5 m; (2) the stocking density was 45-60 fingerlings/m2 (fingerlings were 1.2-2.0 cm in height); (3) there was efficient use of chemicals/drugs; (4) manufactured feed quantity was 800-1,000 tons/ha/crop (feed conversion ratio (FCR) about 1.6); (5) stocking duration was 5-7 months; and (6) fish were harvested at about 1.0 kg. Phan et al. (2009) found that the yield per crop was positively and linearly correlated ($p < 0.05$) to stocking density, pond water depth, but not to pond surface area, and that yields were significantly higher ($p < 0.05$) in ponds in upper provinces and near main rivers compared to those of lower provinces and channels.

Source: https://www.google.com.vn/#q=map+of+the+mekong+delta

Fig. 1. Locations of the surveyed striped catfish farms in the Mekong Delta, Vietnam.

The objective of this study is to evaluate the effects of various geographical locations on costs and returns for the striped catfish grow-out business in the Mekong Delta. A number of related variables and conditions for each pond are taken into account. The variables are interrelated in such a way that their different effects cannot be interpreted meaningfully if they are examined separately. Multivariate techniques therefore have to be apply to statistical analysis. Our goal is to provide suggestions for improving farming management, thereby increasing the profitability of catfish farming in this area.

II. MATERIALS AND METHODS

We examine three study sites located at upstream, midstream and downstream areas of the Hau River (Fig. 1), one of two main branches of the Mekong River System in Vietnam, including the An Phu, Chau Doc districts (An Giang province), Thot Not district (Can Tho city), and Tieu Can, Cau Ke districts (Tra Vinh province).

Data were collected through a structured questionnaire, farm visits, and interviews with farmers during the period from July – August 2011. Samples were randomly selected based on a list of farms in the study areas provided by the local authorities. Data were collected for a total of 120 ponds on 88 farms and retained for further study after carefully examining and excluding invalid responses (upstream site: 40 ponds from 29 farms; middle stream site: 40 ponds from 28 farms; downstream site: 40 ponds from 31 farms).

The datasets included biological and economic information. The biological data included water surface area (ha/pond), water depth (m), stocking density (fingerlings/m^2), survival rate (%), fingerling size (cm high), feed conversion ratio (FCR), harvesting size (kg/fish), grow-out period (months), and production (kg/ha/crop). The economic data included total revenue (according to the sale price at the farm gate and amount of production collected) and production cost. The production cost was separated into two parts, fixed and variable costs.

The fixed costs were comprised of capital depreciation costs for pond construction and equipment. Equipment capital included capital invested in storage facilities, electric generators, water pumps, fences, boats, nets, etc. Variable costs included fingerling, feed, labor, medication, energy, pond sanitation, harvesting, and interest costs.

In this study, the straight-line method was used to calculate depreciation costs. It was assumed that there was the depreciation for pond construction and equipment capital amounts for 10 years and 5 years, respectively, with a salvage value of zero. Striped catfish were harvested three times every two year period, therefore pond construction and equipment depreciation costs were calculated by dividing the corresponding capital by 15 and 7, respectively. The capital amounts were converted into equivalent monetary values based on the conversion rate published by the International Monetary Fund for 2011 (IMF, 2011).

The two sets of variables for evaluating management performance were carefully determined based on the production cost. The first set included the important input intensities for fixed, fingerling, feed, medication, energy and interest costs (for a detailed explanation please see the results section below). The input intensity variables were measured by taking into consideration the corresponding input expenses per ha of water surface area (in thousand VND/ha/crop; in 2011, 1 US Dollar = 20.8 thousand VND). The other set was comprised of the profitability variables, defined here as the ratio of net revenue to the costs of corresponding input items. The net revenue was obtained by subtracting the production cost from the total revenue. Consequently, the profitability variable was measured based on the net revenue, produced at a cost of one thousand VND for the specified input item.

A one-way (location) multivariate analysis of variance (MANOVA) was applied to examine the effects of different geographical locations on the management and economic performance (Miao, 2011). Principal component analysis was further conducted to evaluate individual economic performance with quantitative comparisons (Johnson and Wichern, 2002). Suggestions on how to improve the profitability were made after considering the set of best principal components in combination with various farming management techniques. Finally, a Cobb-Douglas production function was used to study the quantitative relationship between the input and output of the production system (Miao, 2012). Evaluation of this quantitative relationship helps to measure the responsiveness of the output to the unit increase of inputs. This function can also demonstrate increasing, unitary or decreasing returns from increasing production scale, depending upon the data. Computer software developed by the SAS Institute (2009) was used for the analysis; the significance level is set at $P = 0.05$.

III. RESULTS

The production costs for striped catfish farming were divided into nine categories including fixed, fingerling, feed, labor, medication, energy, pond sanitation, harvest, and interest costs. Their corresponding percentage distributions were 1.84, 6.31, 82.18, 0.82, 3.04, 1.64, 0.37, 0.54 and 3.26%, respectively. Due to the fact that input intensities for labor, pond sanitation and harvest costs were very low (only 1.73% of the total production costs) they were not considered to have an important effect on farming. Fixed, fingerling, feed, medication, energy and interest costs were the major variables, accounting for 98.27% of the total production costs. Therefore, these variables were included in further analysis. Tables 1 and 2 show the statistics for production costs and profitability variables for striped catfish ponds in the three study areas.

The MANOVA results indicate that the factor of geographical location had a significant effect (at $P < 0.0001$) on the input costs and varied profitabilities (Table 3). Table 4 displays the data for total production cost, net revenue and profitability for the three study sites. There are many significant differences in biological variables such as stocking density, fingerling size, survival rate, growth period, harvest size, and production at upstream, middle stream and downstream sites (Table 5). A significant correlation between biological variables can be observed (Table 6). Other related information from interviewed respondents is recorded in Table 7.

There was a high correlation between fixed and fingerling costs ($r = 0.1947$, $p = 0.0346$); fingerling and energy costs ($r = 0.2255$, $p = 0.0141$); fingerling and interest costs ($r = 0.1863$, $p = 0.0434$); medication and energy costs ($r = 0.4930$, $p < 0.0001$), and energy and interest costs ($r = 0.2279$, $p = 0.0131$) (Table 8).

The results obtained from further study of the correlation matrix of the production cost variables (Table 8) show that the principal component eigenvalue of the total variance was 6 (Table 9). The first principal component (Z_1) had a variance of 3.9082, accounting for 65.14%, the second component (Z_2) had a variance of 0.7500, accounting for 12.50%, the third (Z_3) for 9.68%, the fourth (Z_4) for 6.11%, the fifth (Z_5) for 4.77% and the sixth (Z_6) for 1.80. Clearly the two principal components Z_1 and Z_2 were more important than the others with statistically acceptable significance. These two principal components, linear combinations of the input intensities, can be formulated as follows (Table 9):

$$Z_1 = 0.3671\text{FC} + 0.4498\text{FG} + 0.4551\text{FD} + 0.3889\text{MD} + 0.4230\text{EN} + 0.3544\text{IN}, \quad (1)$$

$$Z_2 = 0.5731\text{FC} + 0.1789\text{FG} - 0.1099\text{FD} - 0.6319\text{MD} - 0.3000\text{EN} + 0.3718\text{IN}, \quad (2)$$

where FC, FG, FD, MD, EN and IN are fixed, fingerling, feed, medication, energy, and interest costs, respectively. A plot of Z_1 against Z_2 (Fig. 2) shows the distribution of production

Table 1. Statistics for the production cost variables (thousand VND /ha/ crop) for striped catfish ponds at the three study sites.

Input costs	Study sites		
	Upstream (Mean ± S.D.)	Middle stream (Mean ± S.D.)	Downstream (Mean ± S.D.)
Fixed	182,251.18 ± 64,034.31[ab]	218,696.83 ± 104,423.95[ab]	68,595.70 ± 18,650.79[c]
Fingerlings	627,481.31 ± 115,596.84[a]	810,827.50 ± 182,004.45[b]	171,576.23 ± 79,242.65[c]
Feed	6,015,397.00 ± 568,193.05[a]	11,875,635.50 ± 925,342.54[b]	3,077,225.00 ± 710,878.56[c]
Medication	172,416.46 ± 44,774.67[ac]	480,751.27 ± 229,611.63[b]	122,974.00 ± 49,299.78[ac]
Energy	159,367.14 ± 34,810.80[a]	235,984.54 ± 143,130.65[b]	22,151.88 ± 27,499.20[c]
Interest	281,337.44 ± 135,907.03[a]	384,072.96 ± 172,967.93[b]	168,842.72 ± 62,248.67[c]

Values (expressed as mean ± S.D.) with different letters in the same row being significantly different from each other ($P < 0.05$).

Table 2. Statistics for the profitability variables (thousand VND/ha/crop) for striped catfish ponds at the three study sites.

Varied profitabilities	Study sites		
	Upstream (Mean ± S.D.)	Middle stream (Mean ± S.D.)	Downstream (Mean ± S.D.)
Fixed	8.79 ± 5.56[ab]	12.16 ± 6.92[abc]	16.10 ± 10.27[bc]
Fingerlings	2.42 ± 1.78[ab]	2.80 ± 1.14[ab]	6.58 ± 3.77[c]
Feed	0.23 ± 0.07[ab]	0.18 ± 0.06[ab]	0.33 ± 0.15[c]
Medication	8.42 ± 3.35[abc]	11.98 ± 26.04[abc]	12.73 ± 22.14[abc]
Energy	8.91 ± 3.49[ab]	15.32 ± 15.68[ab]	73.25 ± 52.58[c]
Interest	7.52 ± 10.97[abc]	7.05 ± 4.64[abc]	7.31 ± 8.02[abc]

Values (expressed as mean ± S.D.) with different letters in the same row indicating significant differences from each other ($P < 0.05$).

Table 3. One-way Manova for input costs and varied profitabilities for striped catfish ponds at the three study sites.

Statistical criteria	Input costs[a]		Varied profitabilities[b]	
	F value	*P* > *F*	*F* value	*P* > F
Wilks' Lambda	128.50	<.0001	12.71	<.0001
Pillai's Trace	46.45	<.0001	11.74	<.0001
Hotelling-Lawley Trace	314.08	<.0001	13.73	<.0001
Roy's Greatest Root	622.20	<.0001	22.45	<.0001

[a] Input costs are shown in Table 1.
[b] Varied profitabilities are shown in Table 2.

Table 4. Average economic efficiency indicators for striped catfish ponds at the three study sites.

Indicators	Study sites		
	Upstream (Mean ± S.D.)	Middle stream (Mean ± S.D.)	Downstream (Mean ± S.D.)
Fixed cost	182,251.18 ± 64,034.31[ab]	218,696.83 ± 104,423.95[ab]	68,595.70 ± 18,650.79[c]
Variable cost	7,385,938.20 ± 584,201.41[a]	14,016,033.70 ± 1,002,367.36[b]	3,644,291.70 ± 736,451.41[c]
Total cost	7,568,189.30 ± 571,303.65[a]	14,234,730.50 ± 1,047,397.57[b]	3,712,887.40 ± 738,433.15[c]
Gross revenue	8,930,814.70 ± 819,088.84[a]	16,394,288.80 ± 1,260,440.78[b]	4,717,573.30 ± 974,969.27[c]
Net revenue	1,362,625.33 ± 450,861.55[a]	2,159,558.31 ± 697,015.42[b]	1,004,685.93 ± 484,779.22[c]
Total profitability	0.18 ± 0.06[ab]	0.15 ± 0.05[ab]	0.28 ± 0.13[c]

Total cost (VND thousand/ha/crop) = fixed cost + variable cost
Gross revenue (VND thousand/ha/crop) = selling price x production
Net return (VND thousand/ha/crop) = Gross revenue – Total cost
Total profitability = Net revenue/Total cost
Values (expressed as mean ± S.D.) with different letters in the same row indicate a significant difference from each other ($P < 0.05$).

Table 5. Statistics for the biological variables for striped catfish ponds at the three study sites.

Items	Study sites		
	Upstream (Mean ± SD)	Middle stream (Mean ± SD)	Downstream (Mean ± SD)
Stocking density (fingerlings/m^2)	47.17 ± 5.70^a	89.35 ± 6.23^b	31.61 ± 6.06^c
Fingerling size (cm high)	2.49 ± 0.46^a	1.83 ± 0.26^b	1.45 ± 0.25^c
Feed conversion ratio (FCR)	1.51 ± 0.08^{ac}	1.63 ± 0.11 ^{b}	1.46 ± 0.17^{ac}
Growth period (months)	6.80 ± 0.56^a	7.44 ± 0.53^{bc}	7.19 ± 0.64^{bc}
Survival rate (%)	78.48 ± 7.78^{ab}	78.35 ± 6.26^{ab}	72.16 ± 3.67^c
Harvest size (kg/fish)	1.01 ± 0.08^{ab}	0.97 ± 0.07^{ab}	0.86 ± 0.08^c
Production (kg/ha/crop)	369,041.93 ± 33,846.65^a	677,449.95 ± 52,084.33^b	194,941.05 ± 40,287.99^c

Values (expressed as mean ± S.D.) with different letters in the same row indicating significant difference from each other ($P < 0.05$).

Table 6. Correlation matrix showing biological variables for striped catfish ponds at the three study sites.

	Stocking density	Fingerling size	FCR	Growth period	Survival rate	Harvest size	Production
Stocking density	1.0000						
Fingerling size	-0.2173 (0.0181)	1.0000					
FCR	-0.1165 (0.2089)	-0.0653 (0.4824)	1.0000				
Growth period	-0.0681 (0.4640)	-0.0452 (0.6273)	0.1916 (0.0377)	1.0000			
Survival rate	-0.4279 (<.0001)	0.0900 (0.3324)	-0.1155 (0.2131)	-0.1349 (0.1452)	1.0000		
Harvest size	-0.3047 (0.0008)	0.1156 (0.2126)	0.1509 (0.1030)	0.4434 (<.0001)	-0.0101 (0.9138)	1.0000	
Production	0.4200 (<.0001)	-0.0777 (0.4030)	-0.1254 (0.1761)	0.1220 (0.1882)	0.3390 (0.0002)	0.3470 (0.0001)	1.0000

Each correlation coefficient (r) is followed by a probability of Ho: $|r| = 0$ shown in parentheses

Table 7. Background information for the respondents interviewed from the study sites.

		Study sites		
		Upstream (Mean ± SD)	Middle stream (Mean ± SD)	Downstream (Mean ± SD)
Production experience (Years)		9.00 ± 1.36^{ab}	8.59 ± 0.96^{ab}	5.71 ± 1.64^c
Pond area (ha/pond)		0.34 ± 0.07^a	0.30 ± 0.04^b	0.14 ± 0.03^c
Pond depth (m)		4.31 ± 0.53^{ab}	4.34 ± 0.43^{ab}	3.17 ± 0.43^c
Fingerling price		1.35 ± 0.28^a	0.91 ± 0.21^b	0.56 ± 0.29^c
Feed price		10.84 ± 0.18^{abc}	10.82 ± 0.45^{abc}	10.82 ± 0.50^{abc}
Break-even price		20.56 ± 1.00^{ab}	21.04 ± 0.93^{ab}	19.17 ± 1.90^c
Selling price		24.27 ± 0.53^{abc}	24.21 ± 0.60^{abc}	24.23 ± 0.45^{abc}
% farmers buying feed from foreign owned companies		34.29	30.30	64.71
% farmers buying feed from Vietnamese companies		65.71	69.70	35.29
Famer's opinion of feed quality	Good (%)	89.66	89.29	93.55
	Not good (%)	10.34	10.71	6.45

Fingerling price calculated by thousand VND/fingerling.
Feed price, break-even price, selling price calculated by thousand VND/kg.
Values (expressed as mean ± S.D.) with different letters in the same row indicating significant differences from each other ($P < 0.05$).

Table 8. Correlation matrix[a] of input intensities.

Input intensity	Fixed	Fingerling	Feed	Medication	Energy	Interest
Fixed	1.0000					
Fingerling	0.1947 (0.0346)	1.0000				
Feed	0.1498 (0.1054)	-0.1407 (0.1285)	1.0000			
Medication	-0.0541 (0.5607)	-0.0698 (0.4525)	0.0805 (0.3862)	1.0000		
Energy	-0.0680 (0.4646)	0.2255 (0.0141)	-0.1498 (0.1055)	0.4930 (<.0001)	1.0000	
Interest	0.1531 (0.0978)	0.1863 (0.0434)	-0.0249 (0.7886)	-0.0206 (0.8250)	0.2279 (0.0131)	1.0000

[a] Each correlation coefficient (r) is followed by a probability of Ho: $|r| = 0$ shown in parentheses.

Table 9. Eigenvalues[a] and eigenvectors[b] computed from the correlation matrix of input intensities.

Principal component	Eigenvalue	Account for in %	Eigenvector, coefficient of					
			Fixed cost (FC)	Fingerling cost (FG)	Feed cost (FD)	Medicine cost (MD)	Energy cost (EN)	Interest (IN)
Z_1	3.9082	65.14	0.3671	0.4498	0.4551	0.3889	0.4230	0.3544
Z_2	0.7500	12.50	0.5731	0.1789	-0.1099	-0.6319	-0.3000	0.3718
Z_3	0.5810	9.68	-0.4955	-0.1408	-0.2095	-0.0844	0.2137	0.7987
Z_4	0.3664	6.11	0.1076	-0.4168	0.3491	0.4099	-0.6575	0.3041
Z_5	0.2866	4.77	0.5278	-0.5204	-0.5025	0.2802	0.3433	0.0416
Z_6	0.1078	1.80	-0.0327	0.5489	-0.6022	0.4425	-0.3677	0.0637

[a] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variance of 6.0000. Thus the first principal component (Z_1) accounts for (3.9082/6.0000)100% = 65.14%, Z_2 accounts for (0.7500/6.0000)100% = 12.50%, etc.

[b] The eigenvectors give the coefficients of the standardized variables (input intensities), e.g., Z_1 = 0.3671FC +0.4498FG +0.4551FD +0.3889MD +0.4230EN +0.3544IN.

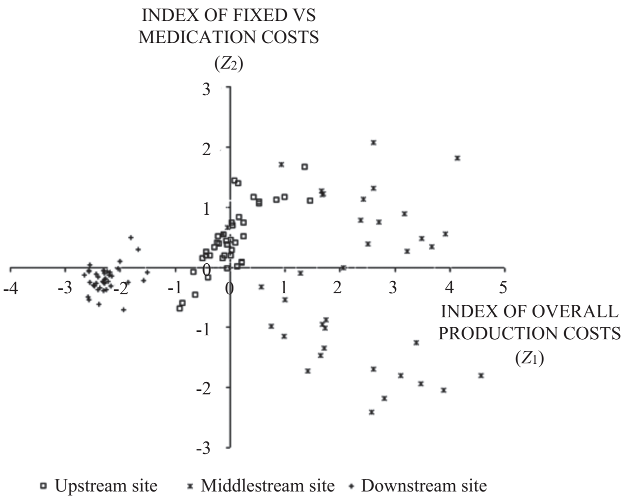

Fig. 2. Distribution of production cost variables for striped catfish ponds at the three study sites based on two principal components (Z_1 and Z_2).

costs (thousand VND/ha/crop) for 120 commercial ponds (calculated per one ha of water surface area) on a two-dimensional plane. Every pond was assigned unique values of Z_1 and Z_2 as a result of these two principal components.

There were highly significant correlations between all profitabilites at $p < 0.05$, excluding the correlation between the medication and energy profitabilities ($r = 0.1706$, $p = 0.0648$) (Table 10). The eigenvalues and eigenvectors, which can be further computed from the correlation matrix (Table 10), show a total variance of 6 (Table 11). The first principal component (I_1) had a variance of 3.4530, accounting for 57.55%, the second (I_2) had a variance of 1.0330, accounting for 17.22%, the third (I_3) accounted for 12.18%, the fourth (I_4) for 5.80%, the fifth (I_5) for 4.10% and the sixth for 3.15%. Clearly the two principal components I_1 and I_2 were more important than the others. According to the eigenvectors of the correlative variables, the I_1 and I_2 functions can be rewritten as follows (Table 11):

$$I_1 = 0.4595FCP +0.4823FGP +0.4831FDP +0.2313MDP +0.4629ENP +0.2347INP, \quad (3)$$

$$I_2 = -0.0761FCP -0.1803FGP -0.0947FDP +0.6720MDP -0.2989ENP +0.6417INP, \quad (4)$$

where FCP, FGP, FDP, MDP, ENP and INP are the fixed, fingerling, feed, medication, energy and interest profitability variables, respectively. In Fig. 3, I_1 is plotted against I_2 where every pond possesses unique values of I_1 and I_2 as a result of these two principal components.

Cobb Douglas production function analysis was used for estimation of the relation of net revenue to independent variables for fixed, fingerling, feed, medication, energy and interest costs. Various methods were used including forward selection, backward elimination, R-square selection, stepwise, maximum R^2 improvement and adjusted R-square selection methods. The goal was to determine the effect of the production cost variables on the net revenue of striped catfish grow-out ponds. There is agreement in the results produced by all methods that only the feed and medication cost variables, with partial significant probabilities of 0.0001 and 0.0269, partial elasticities of 0.8105 and -0.1856, respectively (Table 12), need to be entered into the model as follows:

$$NR \text{ (Net Return)} = 40.1856 * (FD)^{0.8105} * (MD)^{-0.1856}.$$

The coefficient of determination (R^2) for the model was 33.92% (Table 12), which indicates that feed and medication costs explained 33.92% of the total variation affecting net returns. It also implies that excluded variables affecting net revenue accounted for 66.08% of the total variation.

Table 10. Correlation matrix[a] of varied profitabilities.

Varied profitabilities	Fixed	Fingerling	Feed	Medication	Energy	Interest
Fixed	1.0000					
Fingerling	0.6502 (<.0001)	1.0000				
Feed	0.7356 (<.0001)	0.7017 (<.0001)	1.0000			
Medication	0.2655 (0.0037)	0.3052 (0.0008)	0.3692 (<.0001)	1.0000		
Energy	0.6510 (<.0001)	0.6603 (<.0001)	0.6326 (<.0001)	0.1706 (0.0648)	1.0000	
Interest	0.3426 (0.0001)	0.3288 (0.0003)	0.3373 (0.0002)	0.2780 (0.0023)	0.2964 (0.0011)	1.0000

[a] Each correlation coefficient (r) is followed by a probability of Ho: $|r| = 0$ shown in parentheses.

Table 11. Eigenvalues[a] and eigenvectors[b] computed from the correlation matrix of various profitabilites.

Principal component	Eigenvalue	Account for in %	Eigenvector, coefficient of					
			Fixed cost Profitability (FCP)	Fingerling cost profitability (FGP)	Feed cost profitability (FDP)	Medication cost profitability (MDP)	Energy cost profitability (ENP)	Interest Profitability (INP)
I_1	3.4530	57.55	0.4595	0.4823	0.4831	0.2313	0.4629	0.2347
I_2	1.0330	17.22	-0.0761	-0.1803	-0.0947	0.6720	-0.2989	0.6417
I_3	0.7307	12.18	0.0531	-0.0443	-0.0723	-0.6843	0.0454	0.7209
I_4	0.3480	5.80	-0.8368	0.3790	-0.0237	0.0592	0.3724	0.1153
I_5	0.2459	4.10	0.2674	0.0517	-0.8262	0.1373	0.4737	0.0011
I_6	0.1894	3.15	-0.0919	-0.7659	0.2633	0.0656	0.5755	0.0121

[a] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variance of 6.0000. Thus the first principal component (I_1) accounts for (3.4530/6.0000)100% = 57.55%, I_2 accounts for (1.0330/6.0000)100% = 17.22%, etc.

[b] The eigenvectors give the coefficients of the standardized profitability variables, e.g., I_1 = 0.4595FCP +0.4823FGP +0.4831FDP +0.2313MDP +0.4629ENP +0.2347INP.

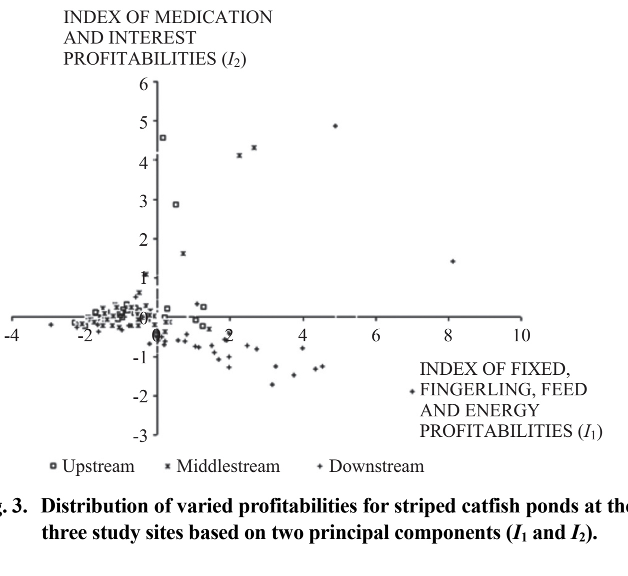

Fig. 3. Distribution of varied profitabilities for striped catfish ponds at the three study sites based on two principal components (I_1 and I_2).

IV. DISCUSSION

Production cost and profitability are the two major concerns in business management. This study analyzes the costs and benefits of striped catfish farming in order to evaluate production effectiveness and provide suggestions for farmers in the three types of geographical locations studied here.

Table 12. Cobb – Douglas function[a] estimated by relating[b] unit net return to input intensities.

	Intercept Log β_0	Feed cost (FD) β_1	Medication cost (MD) β_2
Estimated parameter	1.6041	0.8105	-0.1856
Standard Error	0.5966	0.1130	0.0828
F Value	7.23	51.45	5.02
$Pr > F$	0.0082	<.0001	0.0269

[a] This function is determined as follows: $NR = \beta_0 (FD)^{\beta 1} (MD)^{\beta 2}$, where NR is unit net revenue (thousand VND/ha/crop), input intensity is in units of thousand VND/ha/crop.

[b] R^2 = 0.3392 and adjusted R^2 = 0.3279.

1. Production Cost

The highest input costs were recorded for middle stream ponds (excluding the fixed cost, which was not significantly different from the upstream ponds). Upstream ponds had the second highest input costs (excluding medication costs which were not significantly different from the downstream ponds), while downstream ponds had the lowest input costs (Table 1). This was also identified by the first component Z_1.

In the first component Z_1 (1), the eigenvectors of production cost variables were highly positive, ranging from 0.3544 to

0.4551. This indicates that Z_1 was mainly determined by the overall varied production costs and, therefore, could be defined as an index measuring the overall production costs for striped catfish ponds at three different sites. The distribution of the Z_1 scores is shown in Fig. 2. The input intensities were highest for middle stream ponds and were driven to the far right in Z_1. In contrast, input intensities were lowest for downstream ponds and were driven to the left. Upstream ponds had intermediate input intensities, correlated with their production costs (Table 4).

Striped catfish farming at the upstream and middle stream sites has undergone a long period of development while farming at downstream sites has only just been practiced in the last few years. The upstream and middle stream farmers had 9.00 and 8.59 years of experience, respectively, while downstream farmers had 5.71 years (Table 7). The highest stocking density was observed at middle stream ponds (89.35 fingerlings/m^2), followed by upstream ponds (47.17 fingerlings/m^2) and then downstream ponds (31.61 fingerlings/m^2). In other words, fish farming was more intensive in upstream and middle stream ponds than in downstream ponds.

The eigenvectors of the fixed and medication cost variables in the second component Z_2 (2), were 0.5731 and -0.6319, respectively, much higher (regardless of plus or minus sign) than the eigenvectors of the fingerling, feed, energy or interest cost variables, 0.1789, -0.1099, -0.3000 or 0.3718, respectively (Table 9). These results indicate that if the fixed cost increased, the Z_2 value would increase and if the medication cost increased, the Z_2 value would decrease. Therefore, Z_2 can be considered to be an index contrasting the fixed cost and medication cost. As can be seen in Fig. 2 the upstream and middle stream ponds received higher Z_2 scores and were driven above in Z_2. The fixed costs were larger for upstream and middle stream ponds than for downstream ponds, because upstream and middle stream sites are normally affected by annual flooding. This means that fishponds at these sites have to be built more solidly, requiring greater capital investment than is necessary for downstream ponds. Fig. 2 also shows that many middle stream ponds had lower scores and were driven below in Z_2. The results suggest that the more intensive farming at middle stream ponds leads to greater risk of epidemic disease and thus greater need for medicine and chemicals than for upstream or downstream ponds. The differences in fixed and medication costs can be identified through examination of the statistics related to the production cost variables (Table 1).

The striped catfish has the ability to sustain swimming performance without breathing air (Lefevre et al., 2011), thus, it can be cultured with a very high stocking density. However, the extremely high density in middle stream ponds could adversely affect the growth of the fish and weaken their resistance to disease. As stated in the Normative Act for better management practices for striped catfish farming (CARD Project, 2009), the stocking density in grow-out ponds should not be more than 60 fingerlings/m^2. Clearly, although the stocking density of upstream ponds (47.17 fingerlings/m^2) might be deemed suitable, the stocking density in middle stream ponds should be reduced.

2. Profitability

The significant variance between the fingerling, feed and energy profitabilites leads to differences in the earning power of striped catfish grow-out ponds in different geographical locations (Table 2). The average net revenue-cost ratio of downstream ponds was the highest (0.28), while there was not a significant difference in the ratios of middle stream ponds (0.15) and upstream ponds (0.18) (Table 4). Medication and interest profitabilities did not have a big effect, being similar at all three sites.

The eigenvectors of fixed, fingerling, feed and energy profitability variables for the first component I_1 (3) were high, 0.4595, 0.4823, 0.4831 and 0.4629, respectively (Table 11). Therefore, I_1 could be defined as an index for fixed, fingerling, feed and energy profitabilities. Any farm scoring highly on I_1 would have a high earning power. The scatterplot (Fig. 3) shows that downstream ponds had higher I_1 scores (driven to the far right in I_1) than upstream or middle stream ponds due to their higher earning power, related to the fingerling, feed and energy profitabilities (Table 2). There was no difference between the I_1 scores of the upstream and middle stream ponds in the I_1-I_2 plane (Fig. 3). This was evidenced by insignificant variance of total profitability between upstream and middle stream ponds (Table 4).

The profitability associated with fingerling cost was highest for downstream ponds, due to having the lowest fingerling price (0.56 thousand VND/fingerling) among the study sites (Table 7). However, the fingerlings in downstream ponds were the smallest (1.45 cm high) and the survival rate was the lowest (72.16%) (Table 5). Fingerlings were distributed from fry hatcheries at upstream and middle stream sites to downstream sites through middlemen. The quality of fingerlings was usually low. Moreover, distances from the nursery to downstream sites were great (more than 100 km), and shipping of big fingerlings was inconvenient because of crowding and a low survival rate. Some downstream farmers felt that fingerlings raised at downstream sites had better survival rates than fingerlings from upstream and middle stream sites. The fingerling size in upstream ponds was significantly larger (2.49 cm high) than in middle stream ponds (1.83 cm high), but there was not significant difference in the survival rate between upstream and middle stream ponds, being 78.48 and 78.35%, respectively (Table 5). According to The Normative Act for better management practices for striped catfish grow-out farming (CARD Project, 2009), fingerlings ranging in size from 1.7 to 2.2 cm high are suitable for culturing. Therefore, it is recommended that producers at downstream sites could increase the survival rate by buying bigger fingerlings, while producers at upstream sites could reduce expenses by purchasing smaller fingerlings.

In addition, more fry hatcheries should be developed at downstream sites to supply quality fingerlings for local grow-out ponds. The size of fingerlings (1.83 cm high) in middle stream sites was suitable for grow-out ponds.

It was clear that the earning power of the feed profitability variable contrasted with the FCR. The feed profitability of downstream ponds was 0.33 (Table 2), significantly higher than that of 0.23 and 0.18 for upstream and middle stream ponds, respectively, while the FCR of downstream ponds was 1.46, significantly lower than the 1.51 and 1.63 of upstream and middle stream ponds, respectively (Table 5). On the other hand, as found in this study, the FCR was positively related to the growth period with a correlation coefficient of 0.1916 (p = 0.0377) (Table 6). This means that a longer growth period would increase the FCR. It is known that international and domestic markets prefer fish weighing 0.8-0.9 kg. Taking this into consideration, producers at upstream and middle stream sites could increase profitability related to feed costs by harvesting fish similar in weight to those raised in downstream ponds (Table 5). However, the fish price fell during the harvesting period for middle stream and upstream ponds. Producers had to extend the culturing period, which resulted in an increase in the weight of harvested fish and decrease in the earning power of feed profitability. It is suggested that the Vietnamese government should encourage mechanisms to allow farmers to manage price volatility. Such mechanisms may include tools to improve information flow (such as website and mobile phone applications that would allow growers to easily access current input and output prices), to encourage effective use of cooperatives, and to facilitate the use of contracting or future markets.

We next examined energy profitability. Downstream ponds are built only 0.75-1.81 m above sea level (MARD, 2006), thus water is exchanged for several hours a day during the culturing period as a consequence of tidal gravity. Farmers rarely have to use petroleum as fuel to pump water, except on some days in the dry season. This tidal water exchange helps to reduce expenses, therefore the stocking density at grow-out ponds at these sites could be higher to increase yield. Upstream and middle stream ponds are located at higher sites, so the water must be pumped, which requires the use of petroleum fuel, thus increasing the expense. There was no significant difference in the energy profitability of upstream and middle stream ponds, but it was less than downstream ponds, being, 8.91, 15.32 and 73.25, respectively (Table 2). In order to increase the energy profitability of upstream and middle stream ponds, various levels of government should put in place suitable policies and build infrastructure to encourage farmers to invest in improved equipment, such as voltage transforming devices so they are able to use electricity instead of petroleum.

The second component I_2 (4) eigenvectors for medication and interest profitability variables had high values (0.6720 and 0.6417, respectively) while the eigenvectors for fixed, fingerling, feed and energy profitability variables had small values (-0.0761, -0.1803, -0.0947 and -0.2989, respectively) (Table 11). This shows that medication and interest profitabilities greatly affected the I_2 value and that I_2 could be considered as an index of the medication and interest profitabilities. The ponds which had higher medication and interest profitabilities would receive higher I_2 scores. From the plot of I_1 against I_2 (Fig. 3), it can be seen that there were two upstream ponds with very high energy profitabilities (42.45 and 63.31), two middle stream ponds and one downstream pond possessing extremely high medication profitabilities (116.56, 122.51 and 143.14, respectively) due to their high I_2 scores. Farmers responsible for these ponds seldom took advantage of loans or applied production techniques well. While, the I_2 scores for the other ponds were small and not clearly significantly different because of the similarity in the medication and interest profitabilities for ponds at the three study sites (Table 2). It is suggested that the Vietnamese government should create suitable initiatives to increase the market price of fish through increasing global awareness of Vietnamese products, to make it easier for growers to borrow production capital at low interest rates and to improve their awareness of integrated disease management in striped catfish farming.

3. Cobb–Douglas Production Function

Results obtained from the Cobb-Douglas production analysis showed the net return (thousand VND/ha/crop) as determined from the input intensities of feed and medication costs (thousand VND/ha/crop). The regression coefficients for feed and medication cost variables were 0.8105 and -0.1856, respectively (Table 12). A 1% increase in the input intensity of the feed cost, resulting from an increase in the production scale, would result in a 0.8105% increase in net returns; whereas, a 1% increase in the input intensity of medication costs would result in a 0.1856% decrease in net returns.

These results indicate that there would be greater benefit to increasing the scale of striped catfish production if more investment was made in feed. It can be said that feed plays an extremely important role out of all the variables related to this industry.

At the present time, commercial feed for aquaculture in Vietnam is mainly supplied by foreign-owned companies. For striped catfish grow-out farming, however, the feed is often provided by joint-stock companies. For example, the percentage of farmers using feed from Vietnamese companies at upstream, middle stream and downstream sites was 65.71%, 69.70% and 35.29%, respectively (Table 7). It should be mentioned that feed products from the Viet Thang Feed Joint-Stock Company took 86.96% of the total market share of all Vietnamese feed companies (Viet , 2010); other Vietnamese feed companies could not afford to compete with foreign-owned companies.

Difficulties faced by Vietnamese feed manufactures include the lack of modern production equipment and essential material sources, which cause feed prices in Vietnam to be higher than in other Asian countries by around 15-20% (Nguyen and Huynh, 2010). The survey results show that the feed cost for grow-out ponds reached around 82.18% of the total operating costs, whereas it accounted for only 75% in 2008 (Phan et al., 2009). A necessary step to reduce the feed costs is to improve the competitiveness of Vietnamese companies. This involves finding better feed processing technologies, using local feed-stuff, and reducing the use of imported materials as much as possible. Furthermore, research on striped catfish nutrition should be improved further. In turn, the results of these studies should be distributed to producers to obtain better feed consumption effectiveness.

The Cobb-Douglas function also considered the input intensity of medication costs. Producers could lose benefits if they had to use a lot of medicine and chemicals. In recent years, farming area and intensive culturing have increased, leading to outbreaks of disease. Several studies have reported that many different disease symptoms had been found in farmed fish (Phan, 2009; Dinh, 2010). In order to control disease, producers used more toxic antibiotics and chemicals with higher frequency and dosages. Antibiotic resistance in the predominant gram-negative bacteria has been discovered in striped catfish in the Mekong Delta (Sarter et al., 2007). This type of development can lead not only to a loss of economic benefits but also pollution of the aquatic environment and harm to consumer health.

Vietnam fishery management organizations from the central to local levels have tried to control the use of toxic antibiotics and chemicals for aquaculture in general and in striped catfish farming in particular. They are striving to apply Global GAP (Good Agricultural Practices) standards and SQF (Safe Quality Food) standards step by step to meet the sanitation and food safety requirements of the international market.

V. CONCLUSION

From our findings, we conclude that there was a reduction in the degree of intensity, production and net revenue in the production system from middle stream ponds, to upstream ponds and finally downstream ponds. However, the earning power of downstream ponds was higher than that of upstream and middle stream ponds. Increasing the scale of production to earn more net revenue could be obtained by increasing the input intensity of the feed cost and reducing the input intensity of the medication cost.

The size of fingerlings in middle stream ponds (1.83 cm high), the stocking density for upstream ponds (47.17 fingerlings/m^2), and the harvested fish weight at downstream ponds (0.86 kg/fish) were deemed suitable. Farmers should apply Global GAP standards and reduce the use of toxic chemicals. The various levels of Vietnamese government should implement suitable initiatives to increase fish prices by increasing global awareness of Vietnamese product, encouraging them to use electricity instead of petroleum for fuel, allowing growers to borrow production capital at low interest rates, improve the competitive capacity of domestic feed processing companies, expand fry nursery areas at downstream sites, and improve awareness of integrated disease management in striped catfish farming.

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