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ORIGINAL RESEARCH

Study on regional production and economy of cobia *Rachycentron canadum* commercial cage culture

Cheng-Ting Huang · Sha Miao · Fan-Hua Nan · Shi-Mu Jung

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Abstract In recent years, cobia has become an emerging farmed species in Asia due to its quick growth and high economic value. This study collects biological and economic data affecting the economic performance of cobia farming in three countries, namely Taiwan, China, and Vietnam. The data are collected by questionnaire sampling and analyzed by multivariate statistical analysis in order to compare the key factors affecting the production and economy of cobia farming in these three countries. The results show that Taiwan, China, and Vietnam have significant differences in input intensities and profitability. China has the highest input intensity (3372.42 TWD/m^3), as its high stocking density increases feed input. Taiwan has the highest unit input cost (103.44 TWD/kg), as the high quality of the product increases the price of cobia in Taiwan, which offsets the high product costs. In terms of profitability, the benefit–cost ratio is over one in all three countries, indicating that the profitability of cobia farming is good in all three countries. Profitability analysis shows that fingerlings in China achieve 36.50, which is the highest among the three countries; whereas Taiwan has the highest feed profitability of 0.78, which reveals that the fingerlings produced in China are competitive in both price and quality, while Taiwan has the best feed management efficiency. The production costs and profitability of Vietnam fall between those of Taiwan and China. Feed cost is the main expenditure in cobia culture; thus, good feed management could effectively reduce production costs and increase business performance. The feed quality and input management model of Taiwan, in conjunction with the fingerling quality and stock model of China, could provide future reference for farming management in such areas as feed input and selection of fingerling.

Keywords Cobia · Cage culture · Production cost · Profitability · Multivariate statistical analysis

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Introduction

Cobia, *Rachycentron canadum*, is a large, migratory, coastal pelagic fish of the monotypic family *Rachycentridae* that is distributed worldwide in tropical and subtropical seas, with the exception of the eastern Pacific (Shaffer and Nakamura 1989; Ditty and Shaw 1992). Cobia belongs to a temperate-zone fish species and grows very quickly. After culturing for one year, its size can reach 6–8 kg, which is suitable for market use, and as all parts of the cobia are utilized, there is high economic product value. The above characteristics have made cobia a popular cage culture species in Asian countries in recent years (Liao et al. 2007).

The commercial industry of cobia cage culture was developed in the 1990s, beginning in Taiwan, and later in China and other Southeast Asian countries. The data of the Food and Agriculture Organization (FAO) indicate that the output of cobia culture continuously increased from 2,626 tons in 2000 to 29,859 tons by 2007, with an output value of $59,984,000 USD (Fig. 1) (FAO 2009). China has the highest product output, with Taiwan ranking second, followed by Vietnam (Fig. 2). Other countries in Southeast Asia have also developed culture techniques; thus, the annual output continues to increase.

Cobia cage culture in Taiwan

After Taiwan's achievements in the artificial propagation of cobia fingerlings in 1994, farmers began commercial cobia culture operations in Penghu and Pingtung, adopting the processes of a phased culture mode, namely broodstock management and mass larval production, nursery, and grow-out (Chang et al. 2007; Huang et al. 2002; Huang et al. 2008; Liao et al. 2004, 2007; Miao et al. 2009). Taiwan's cobia output increased from 1,476 tons in 1999 to 4,544 tons in 2007, due in part to the favorable sea environments of different culture regions. A variety of cage structures thus can be divided into rigid and non-rigid cage nets, according to the material of the floating collar. In terms of the floating or submerged methods, cage nets can be divided into floating nets and submergible nets (Nan 2007). Although Taiwan's cobia culture developments and techniques have reached

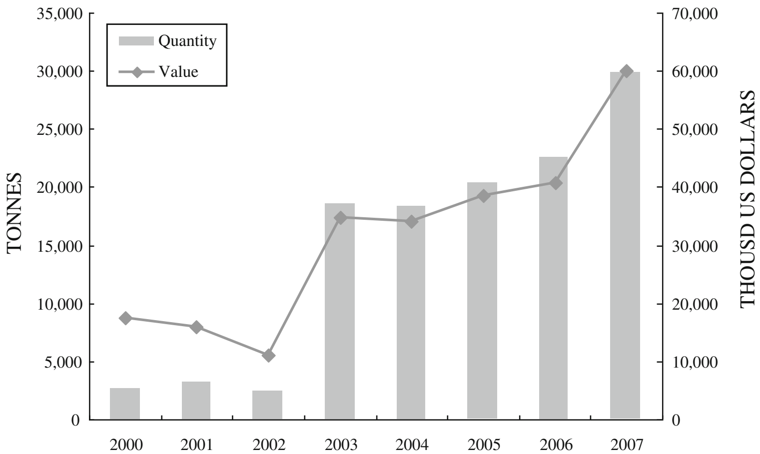

Fig. 1 Statistics of production of global cobia culture. *Source*: FAO 2009

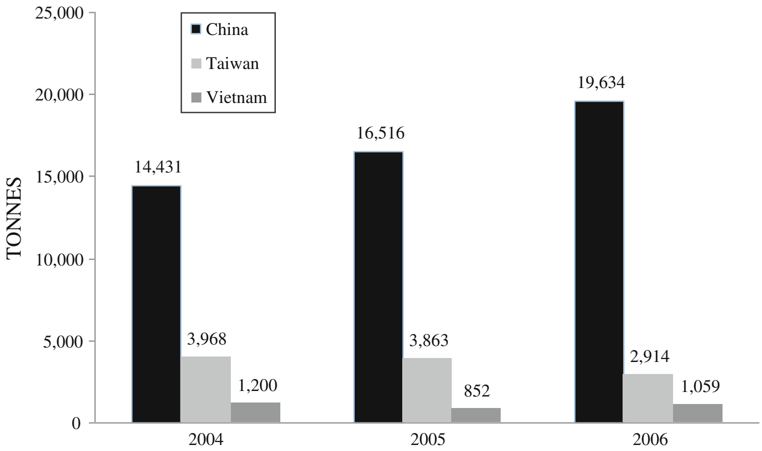

Fig. 2 Statistics of production of cobia farming in China, Taiwan, and Vietnam in 2004–2006. *Source*: China, Taiwan (FAO 2009). Vietnam (statistics of Vietnam exporters of aquatic products)

maturity, the industry is subject to natural disasters. In Taiwan, the main problem faced by the cobia culture industry is the impact of natural disasters, such as the typhoons that often occur, causing great damages to the culture system each year. Serious typhoon disasters in recent decades include Typhoon Zeb (Nov. 1998), Typhoon Dan (Oct. 1999), Typhoon Chebi (Jun. 2001), and Typhoon Haitang (Jul. 2005), which resulted in heavy losses for farmers with culture cages (Ku and Lu 2001). An additional problem is chilling injury, as the cobia is a warm-water fish and requires the optimal temperature range of 22–32°C. When the temperature decreases to 20°C, feeding activities are reduced, and temperatures below 14°C may lead to high mortality rates (Sun et al. 2006a; Miao et al. 2009). Penghu is located in the open seas in the west of Taiwan, where the average water depth is shallow and subject to continental air flows in the winter, which lower water temperatures and increase mortality rates. In 1996, 1999, and 2007, lower water temperatures caused a 60% mortality rate of cobia in the Penghu region (Ku et al. 2000). Natural disasters such as typhoons and lower temperatures are major factors affecting cobia culture development in Taiwan and have caused a sluggish annual output of 3,500 tons (Su et al. 2000; Liao et al. 2004).

The cobia market in Taiwan can be divided into export and domestic markets. Initially, the cobia domestic market was consumed as sashimi; however, cobia products have become diversified under the research and development of Taiwanese farmers and are currently provided globally through electronic media and the Internet. The transparency of the product has been obviously increased, thus enhancing broad customer acceptance. The export market products can be divided into fish fillets and sashimi, with fillets mainly exported to European and American markets and sashimi largely exported to Japan and Korea (Liao et al. 2004, 2007; Miao et al. 2009). However, the main market remains in Taiwan, due to a lowered output of cobia.

Cobia cage culture in China

With China's success in the artificial propagation of cobia fingerlings, farmers began immediately to engage in the cobia cage culture industry and, through continuous expansion, reached the total output of 19,634 tons by 2006, ranking first in the world (FAO 2009). The cobia-farming regions are located in the southern areas of China, namely Guangdong and Hainan provinces (Zhou et al. 2004, 2007; Sun et al. 2006a, b). In the beginning, trash fish was used as feed for cobia; however, this source of fresh feed was subject to seasonal factors, which caused great price fluctuations. Thus, research institutions began to develop artificial cobia feed in order to stabilize cobia quality and industry scale (Zhou et al. 2004, 2006; Wang et al. 2005).

China's cobia cage nets can be divided into two types, namely a high-density polyethylene round Norwegian type and a rectangular fish raft type, built from wood and bucket floats. The round cage net was developed by the China National Petroleum Corporation (CNPC), which cooperates with private companies in the cobia culture industry. CNPC provides culture facilities and artificial feed, while the private farmers manage and operate the farms, which results in an industry scale that is much larger than would be possible with only farmers. The main farming regions of joint operations are located in Jinpai, Hainan, Linggao, Lingshui, and Sanya, and other coastal areas, where, in addition to cobia, high economic value rockfish and golden pompano are cultured. Fish raft cage nets are mainly used by individual farmers in cobia-farming regions situated in Yangpu, Wenchang, Hainan, etc. Initially, cobia fingerlings were exported from Taiwan; however, more recently, private farmers and research institutions have developed mature techniques for culturing artificial fingerlings, thus gradually reducing fingerling imports from Taiwan. Moreover, some fingerling farmers occasionally export fish fry or fingerlings to Taiwan or Vietnam. In China, the cobia culture output has continuously increased by thousands of tons, and the main consumer market remains the domestic market. Only a few farmers export their products to European and North American countries, accounting for a low percentage, and the majority of cobia sales in China rely on domestic markets.

Cobia cage culture industry in Vietnam

Vietnam has a coast line 3,260 km long with many inner-bay sea areas suitable for cage culture on the sea surface. Due to the rapid growth and high economic value of cobia, Vietnam began developing its cobia cage culture in 1999. Presently, its annual output is about 1,000 tons. The farming regions are situated in Hai phong, Quang ninh, Nghe an, Khanh hoa, and Vung tau. Initially, cobia fingerlings were imported from China and Taiwan; however, the Research Institute for Aquaculture No.1 adopted intensive and semi-intensive systems to cultivate cobia fingerling. In 2005, the output was 100,000 fingerlings, with sizes ranging from 10 to 15 cm, providing a stable source of fingerlings for farmers (Niels and Nguyen 2005; Nguyen et al. 2006). However, due to the low output, cobia fingerling continues to rely on imports. Regarding culture systems, traditional cage net culture farmers in Vietnam use fish rafts, which are made of wood and bucket floats. In the Nghe an and Phu Yen areas, foreign investors have introduced the Norwegian rigid round cage net, where one-year fingerling cultures reached the size of 6–8 kg, which is suitable for market use. The main markets are China and Taiwan.

Taiwan, the Hainan Province in China, and Vietnam are all situated in east and Southeast Asia (Fig. 3). However, geological differences may affect the growth conditions of fingerlings, and the economic levels of the different countries may affect the production input capabilities of the farms. Huang et al. (2008) and Miao et al. (2002, 2009) reported that cost inputs and economic efficiencies of the culture industry may vary due to the different production regions. Therefore, this study collects ecological and economic

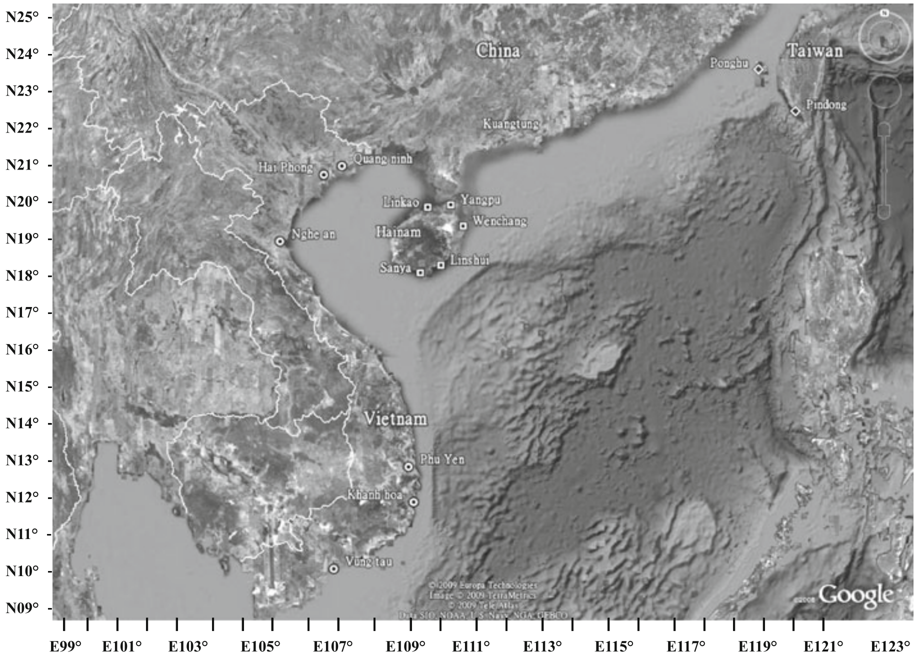

Fig. 3 Geographical locations of cobia farms in Taiwan, China, and Vietnam. *Source*: Google (2009)

variables of cobia farming in Taiwan, China, and Vietnam and employs multivariate statistical analysis in order to compare the culture industry production and economies of the regions in order to determine the key factors of production efficiency and provide reference for future cobia culture investors.

Materials and methods

Production and economic data were collected by a questionnaire that was used to interview cobia farmers in Pingtung and Penghu, Taiwan; Yangpu, Linggao, and Sanya, China; and Phu yen, Khanh hoa, and Vung tau, Vietnam (Fig. 3) for analysis by stratified random sampling (Shang 1990). The survey was conducted during the summers of 2006 and 2007, and the collected data were divided into biological and economic categories. The biological data contained farming area, stocking density, and survival rate, while the economic data included production costs and profits. After eliminating incomplete samples, there were 22 valid samples, including nine from Vietnam, five from China, and eight from Taiwan. The nine farms in Vietnam have a cumulative contribution of 95% of the total annual production. The eight farms in Taiwan have a cumulative contribution of 85% of the total annual production. The data collected from cobia farmings in China contain Norway cages and wood cages. Selection and investigation of representative farms are based on large-scale production of over 200 tons per year.

To evaluate the farming productivity of cobia in different countries, this study selected data of production costs and profitability, as collected from the original survey data, which serves as input for the key factors affecting profits. The annual production cost in the cobia cage culture was separated into two parts, fixed and variable costs. Investment of cage, in farms of fixed cost, has been depreciated already. Variable costs in production contain feed cost, fingerling cost, labor cost, and others (water, electricity, maintenance, medicines, etc.). Variables of costs can be divided into input intensity (input cost/m^3) and unit input cost (input cost/kg). These input intensities were measured by their corresponding input expenses (in Taiwan dollars) based on a 1-m^3 cage water. These unit input cost variables were measured by their corresponding input expenses based on a 1-kg fish weight. Prior to data analysis, this study converted the currencies into TWD (1 TWD: 500 VND: 0.21 RMB: 0.031 USD), according to the exchange rate at the time of farm survey, for subsequent statistical analysis.

Profit variables include total revenue, net revenue, benefit–cost ratio (B/C), and profitability. The total revenue (for each individual farming) was estimated by unit price ($/kg) offered by big buyers (directly exchanged at farms) multiplied by the total production (kg). The net revenue was obtained by subtracting the annual production cost from the total revenue. The profitability variables include feed profitability, fingerling profitability, labor profitability, and other profitability, which are similar to the productivity variables, with the exception of focus, which is net earnings instead of total revenues. Consequently, a profitability variable was measuring the net revenue that was produced at a 1-dollar cost based on a certain input item.

Upon selection of the variables, this study conducted one-way MANOVA, Mahalanobis distance, and canonical discriminant functions for analysis in order to determine the key factors affecting profitability during the production of cobia in Taiwan, China, and Vietnam. One-way (location) multivariate analysis of variance (MANOVA) (Johnson and Wichern 1988) was applied to examine the effects of geographical location. The Mahalanobis distances (Mahalanobis 1948; Manly 1986) among the three countries were first calculated using the three sets of variables, respectively, to verify the differences in performance. The analysis of canonical discriminant functions (Fisher 1936; Hair et al. 1987) was further utilized in order to distinguish the three country's performances with visual aids. Due to computing of the canonical discriminant functions, the corresponding canonical variables might indicate a group of quantified management indices and thus provide the farming systems with improved space in the future. A computer software developed by the SAS Institute was used.

Results

Tables 1 and 2 present the input intensity (TWD/m^3) and unit input cost (TWD/kg), respectively, in Taiwan, Vietnam, and China. The input intensity results indicate that China has the highest feed input intensity of 3372.42 TWD/m^3, which is twice that of Vietnam and Taiwan, while Taiwan has the highest fingerling input intensity of 200.33 TWD/m^3 (Table 1, Fig. 4). The input intensities of the different countries have significant differences ($\alpha < 0.1$), according to multivariate statistical analysis (Table 6). The average production cost of cobia per kg is 85.32 TWD/kg in China and is comprised of feed costs 83.35 TWD/kg, fingerling costs 0.93 TWD/kg, labor costs 0.84 TWD/kg, and other costs 0.20 TWD/kg. In Taiwan, the average production cost is 103.44 TWD/kg, which is comprised of feed costs 88.55 TWD/kg, fingerling costs 11.25 TWD/kg, labor costs 3.22 TWD/kg, and other costs 1.81 TWD/kg. In Vietnam, the average production cost of cobia is 86.82 TWD/kg and is comprised of feed costs 73.44 TWD/kg, fingerling costs 3.53 TWD/kg, labor costs 3.60 TWD/kg, and other costs 6.25 TWD/kg (Table 2).

Table 1 Statistics of input intensities for studied farms in cobia cage culture

Country	Number of farms (n)	Feed (FD)[b,c]		Fingerling (FG)[b,d]		Labor (LR)[e]		Other (OR)[f]	
		Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE
China	5	3372.42	1188.21	40.40	14.46	41.63	20.71	12.91	7.98
Taiwan	8	1691.17	199.67	200.33	54.59	66.11	43.86	38.11	28.74
Vietnam	9	1629.66	359.37	74.61	16.13	53.52	21.76	49.14	12.92

[a] The unit is 1 Taiwan dollar per 1 m^3 water. One US dollar is equal to 31.8 TWD

[b] It has significant difference after statistical analysis ($\alpha < 0.1$)

[c] Feed input intensity (TWD/m^3) = feed cost (TWD)/aquaculture water (m^3)

[d] Fingerling input intensity (TWD/m^3) = fingerling cost (TWD)/aquaculture water (m^3)

[e] Labor input intensity (TWD/m^3) = labor cost (TWD)/aquaculture water (m^3)

[f] Other input intensity (TWD/m^3) = other cost (TWD)/aquaculture water (m^3)

Table 2 Statistics of unit input costs for studied farms in cobia cage culture

Country	Number of farms (n)	Feed[c]		Fingerling[b,d]		Labor[e]		Other[f]		Total	
		Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE	Mean[a]	SE
China	5	83.35	7.69	0.93	0.07	0.84	0.50	0.20	0.10	85.32	7.16
Taiwan	8	88.55	8.50	11.25	3.38	3.22	2.06	1.81	1.29	103.44	6.13
Vietnam	9	73.44	5.59	3.53	0.31	3.60	2.11	6.25	3.15	86.82	5.67

[a] The unit is 1 Taiwan dollar per 1 kg fish weight

[b] It has significant difference after statistical analysis ($\alpha < 0.1$)

[c] Feed cost input (TWD/kg) = feed cost (TWD)/output (kg)

[d] Fingerling cost input (TWD/kg) = fingerling cost (TWD)/output (kg)

[e] Labor cost input (TWD/kg) = labor cost (TWD)/output (kg)

[f] Other cost input (TWD/kg) = other cost (TWD)/output (kg)

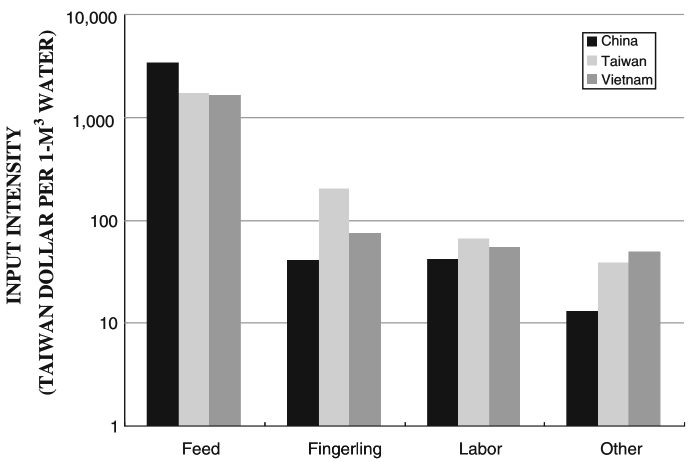

Fig. 4 Comparison of cost input intensities of cobia farming in Taiwan, China, and Vietnam

The feed costs account for the highest percentage, and the unit input costs of the three regions have significant differences ($\alpha < 0.1$) (Table 6), according to multivariate statistical analysis.

Based on the profitability data, China has the highest fingerling, labor, and other profitabilities, while Taiwan has the highest feed profitability of 0.78 (Table 3). Regional profitability has significant difference ($\alpha < 0.05$) (Table 6), as based on MANOVA result. China has the highest total revenue (4319.76 TWD/m^3), while Taiwan has the highest average net revenue (1180.93 TWD/m^3) and benefit–cost ratio (1.63) (Table 4).

The results of the biological factors are shown in Table 5. The initial stocking density (fingerling number/m^3; g/m^3) of the different farms is the highest in China. The survival

Table 3 Statistics of profitabilities for studied farms in cobia cage culture

Country	Number of farms (n)	Feed profitability[a] (FDP)		Fingerling profitability[b,e] (FGP)		Labor profitability[c] (LRP)		Other profitability[d] (ORP)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
China	5	0.39	0.11	36.50	12.12	3918.93	3420.78	13.72	4.11
Taiwan	8	0.78	0.16	10.26	2.78	1261.18	603.61	7.10	2.20
Vietnam	9	0.51	0.11	10.91	2.53	32.07	8.96	6.00	2.93

[a] Net revenue divided by total feed cost

[b] Net revenue divided by total fingerling cost

[c] Net revenue divided by total labor cost

[d] Net revenue divided by total other cost

[e] It has significant difference after statistical analysis ($\alpha < 0.001$)

Table 4 Statistics of revenue for studied farms in cobia cage culture

Country	Number of farms (n)	Total revenue		Net revenue[a]		Benefit–cost ratio[b]	
		Mean[c]	SE	Mean[c]	SE	Mean	SE
China	5	4319.76	1224.53	852.40	114.39	1.38	0.10
Taiwan	8	3176.65	256.52	1180.93	189.46	1.63	0.12
Vietnam	9	2586.30	529.02	779.39	239.07	1.48	0.09

[a] Total cost subtracted from total revenue gives net revenue

[b] Benefit–cost ratio of total revenue to total cost

[c] The unit is Taiwan dollar per 1 m^3 cage water

Table 5 Statistics of biological original variables for studied farms in cobia cage culture

Country	Number of farms (n)	Stocking density (fingerling/m^3)		Stocking density (g/m^3)		Survival rate[a]	
		Mean	SE	Mean	SE	Mean	SE
China	5	8.40	3.24	41.97	16.18	0.76	0.06
Taiwan	8	7.93	0.66	39.65	3.32	0.35	0.02
Vietnam	9	4.74	1.21	23.54	6.12	0.75	0.05

[a] It has significant difference after statistical analysis ($\alpha < 0.0001$)

Table 6 One-way MANOVA analysis of studied farms in cobia cage culture

Factor	Statistical criteria	Input intensity		Unit input cost		Profitability		Biological original variables	
		F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Location[a]	Wilks' Lambda	2.17	0.0579	2.04	0.0736	3.15	0.0096	8.79	<0.0001
	Pillai's Trace	2.14	0.0587	1.97	0.0805	2.61	0.0241	5.75	0.0003
	Hotelling-Lawley Trace	2.25	0.0664	2.15	0.0773	3.79	0.0070	12.84	<0.0001
	Roy's Greatest Root	3.94	0.0193	3.95	0.0190	7.75	0.0010	26.73	<0.0001

[a] Conducting a test of null hypothesis that the main effect means (expressed in mean vectors) caused by the factor of geographical location are not statistically different. The test, namely, is H_0: $\vec{\mu}$China = $\vec{\mu}$Taiwan = $\vec{\mu}$Vietnam. $\vec{\mu}$China, $\vec{\mu}$Taiwan and $\vec{\mu}$Vietnam are the mean vectors considering the input intensity, unit input cost, profitability and biological original variables obtained from the cobia farms located in China, Taiwan, and Vietnam, respectively

rate is the highest in China, followed by Vietnam and Taiwan ($\alpha < 0.0001$). The multivariable statistical analysis results of biological original variables have significant differences (Table 6; $\alpha < 0.0001$).

Mahalanobis distances are used for the analysis of input intensity and profitability, and the results indicate that Taiwan and China have the greatest distance of input intensities, which have a significant difference ($\alpha = 0.0213$), based on statistical analysis. Taiwan and Vietnam have the smallest distance between input intensities and show insignificant difference ($\alpha = 0.2411$) (Table 7), according to statistical analysis. Taiwan and China have the greatest distance in profitability, which reflects a significant difference ($\alpha = 0.0016$) after statistical analysis, while Taiwan and Vietnam show insignificant difference ($\alpha = 0.2758$) (Table 9).

For the analysis results of canonical discriminant functions, input intensities are listed in Table 8. The canonical discriminant function equations are as follows:

$$\mathrm{CAN1} = -\ 0.7064\mathrm{FD} + 1.0765\mathrm{FG} - 0.3836\mathrm{LR} + 0.6049\mathrm{OR}$$
$$\mathrm{CAN2} = +0.4395\mathrm{FD} + 0.5045\mathrm{FG} + 0.9100\mathrm{LR} - 1.0740\mathrm{OR}$$

The eigenvalues of CAN1 and CAN2 are 0.9263 ($\alpha = 0.0579$) and 0.2332 ($\alpha = 0.3001$), respectively. Fingerling input intensity (1.0765) is the major variable, which causes CAN1 to approach $X > 0$, and feed input intensity (−0.7064) causes CAN1 to approach $X < 0$. The factors affecting the value of CAN2 are labor input intensity (0.9100) and other input intensity (−1.0740). However, the eigenvalue of CAN2 is lower and has no

Table 7 A matrix of Mahalanobis distance[a] (input intensity variables) between three locations of cobia cage culture in Taiwan, China, and Vietnam

	China	Taiwan	Vietnam
China	0 (1.0000)	5.7192 (0.0213)	2.9432 (0.1444)
Taiwan	5.7192 (0.0213)	0 (1.0000)	1.7148 (0.2411)
Vietnam	2.9432 (0.1444)	1.7148 (0.2411)	0 (1.0000)

[a] Mahalanobis distance was expressed considering the four input intensity variables including feed input intensity, fingerling input intensity, labor input intensity and other input intensity

Table 8 Canonical discriminant functions analysis of three locations based on input intensity variables

Input intensity variables	Canonical variables and related coefficients	
	CAN1	CAN2
Feed (FD)	−0.7064	0.4395
Fingerling (FG)	1.0765	0.5045
Labor (LR)	−0.3836	0.9100
Other (OR)	0.6049	−1.0740
Eigenvalue	0.9263	0.2332
Approximated F	2.17	1.32
Pr > F	0.0579	0.3001

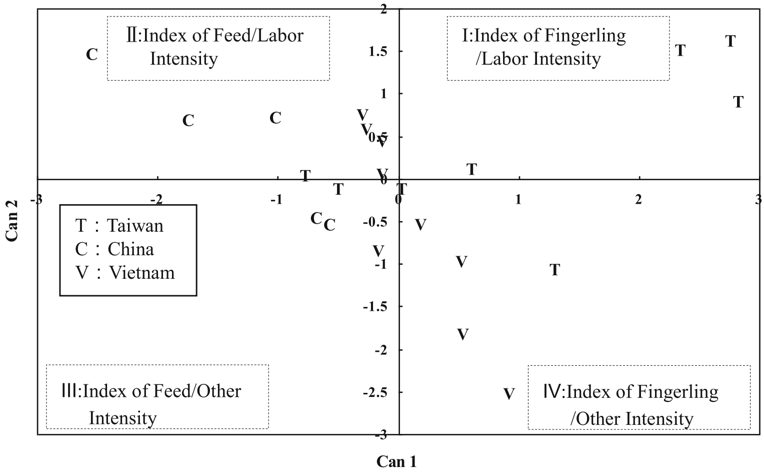

Fig. 5 Distribution of three countries' cobia farming on two canonical variables (CAN1 and CAN2) computed by input intensity variables

reference value. In this paper, CAN2 is utilized to draw a distribution map of the fall points of canonical discriminant functions. The actual parameters of the farmers are substituted into the equation of canonical discriminant functions in order to illustrate the figures of CAN1 and CAN2 and define the impact indices of the quadrants (Fig. 5). The fall points of the farmers of the three countries, as shown in the figure, distinguish the cost input indices. More farmers in Taiwan are distributed within the fingerling and labor input intensities indices, while Vietnam inclines to fingerling and other input intensity indices, while feed input intensity in China has the greatest affect.

The profitability results, as computed by canonical discriminant functions, are displayed in Table 10. The equations are as follows:

$$\mathrm{CAN3} = 1.0040\mathrm{FDP} - 2.0163\mathrm{FGP} + 0.6541\mathrm{LRP} + 0.3171\mathrm{ORP}$$
$$\mathrm{CAN4} = 0.5383\mathrm{FDP} - 0.2942\mathrm{FGP} + 0.8455\mathrm{LRP} + 0.3891\mathrm{ORP}$$

The eigenvalues of CAN3 and CAN4 are 1.8236 ($\alpha = 0.0096$) and 0.1309 ($\alpha = 0.5419$), respectively. The major variable, which causes CAN3 to approach X > 0, is feed profitability (1.0040), while the major variable, which causes CAN3 to approach X < 0, is fingerling profitability (−2.0163). The main factors affecting the value of CAN4

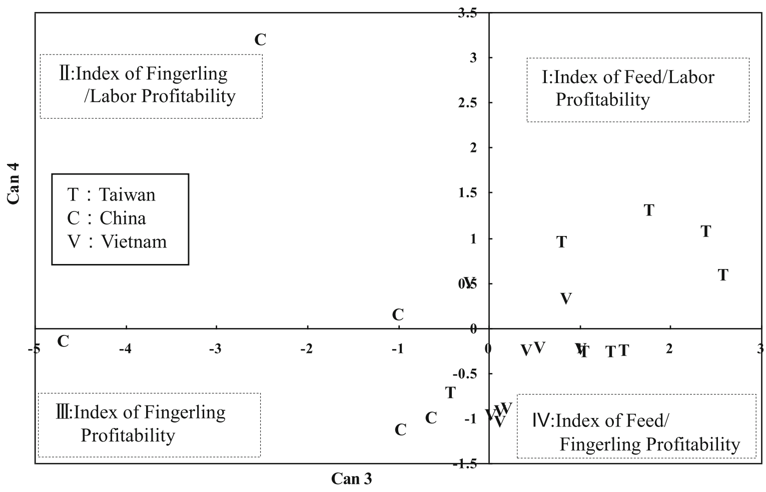

Fig. 6 Distribution of three countries' cobia farming on two canonical variables (CAN3 and CAN4) computed by profitability variables

Table 9 A matrix of Mahalanobis distance[a] (profitability variables) between three locations of cobia cage culture in Taiwan, China, and Vietnam

	China	Taiwan	Vietnam
China	0 (1.0000)	11.1603 (0.0016)	5.7055 (0.0222)
Taiwan	11.1603 (0.0016)	0 (1.0000)	1.5805 (0.2758)
Vietnam	5.7055 (0.0222)	1.5805 (0.2758)	0 (1.0000)

[a] Mahalanobis distance was expressed considering the four profitability variables including feed profitability, fingerling profitability, labor profitability, and other profitability

Table 10 Canonical discriminant functions analysis of three locations based on profitability variables

Profitability variables	Canonical variables and related coefficients	
	CAN3	CAN4
Feed profitability (FDP)	1.0040	0.5383
Fingerling profitability (FGP)	−2.0163	−0.2942
Labor profitability (LRP)	0.6541	0.8455
Other profitability (ORP)	0.3171	0.3891
Eigenvalue	1.8236	0.1309
Approximated F	3.15	0.74
Pr > F	0.0096	0.5419

are labor profitability (0.8455) and fingerling profitability (−0.2942). The eigenvalue of CAN4 is lower; thus, the reference value is lower. The actual parameters of the samples are substituted into the equation of canonical discriminant functions in order to illustrate the figures of CAN3 and CAN4 (Fig. 6). The figure distinguishes the business performances of the different farms, as well as the profitability variables of the locations of farms in different countries. Taiwan's profitability is affected by the feed and labor profitability indices, while the farmers in Vietnam are distributed in an area where feed and fingerling profitability indices are located. The main variable affecting the profitability of Chinese farmers is fingerling profitability.

Discussion

Economic performances of aquacultures are determined by production costs and revenues during culture processes. Management and control of these costs have both direct and indirect impact on the profitability of the industry (Miao et al. 2009; Huang et al. 2008). Cobia farming has been developed in Asian countries over the last ten years, and the farming model of each country has advantages and disadvantages. Therefore, this study collects input and output data from sampled farmers in Taiwan, China, and Vietnam, which are currently the largest output countries of cobia, in order to analyze the economic performances of farms and discuss the advantages and disadvantages of regional farming conditions and management methods. For economic performance analysis, the four direct costs, including feed costs, fingerling costs, labor costs, and other costs, as well as unit input cost and production costs are used to compare the differences of cobia-farming management in Taiwan, China, and Vietnam. The statistical data of unit input intensities in Table 1, Fig. 4 indicate that feed input intensity accounts for the highest percentage in the different countries, accounting for 97.26% of the total cost in China, 84.74% in Taiwan, and 90.19% in Vietnam. A one-way (location) multivariate analysis of variance (MANOVA) is applied to examine the effect of geographical location. For the differences in individual costs in the different countries, the feed input intensity in China is twice that of Taiwan and Vietnam ($\alpha < 0.1$). Taiwan has the highest fingerling and labor input intensity, while Vietnam has the highest other input intensity (Table 1). The input intensities and unit input costs of the three countries have significant differences ($\alpha < 0.1$) (Table 6).

Measuring Mahalanobis distance considers the studied multivariate in order to evaluate the difference between two objects; if two objects have similar mean measurements, then they are 'close', whereas if they have different mean measurements, then they are 'distant' from each other. If α is set as 0.10, then the three countries considering the input intensity variables are significantly different from one another (Table 7). Mahalanobis distances are used for the analysis of input intensity and profitability, and the results indicate that Taiwan and China have the greatest distance of unit input intensities and profitability, $\alpha = 0.0213$ and $\alpha = 0.0016$, respectively, based on statistical analysis. Taiwan and Vietnam have the smallest distance between cost input intensities and profitability, showing insignificant difference, $\alpha = 0.2411$ and $\alpha = 0.2758$, respectively (Tables 7 and 9).

The objective of canonical discriminant functions analysis is to take p variables X_1, $X_2,\ldots,X_p$ and find their combinations to produce indices Z_1, $Z_2,\ldots,Z_p$ or so-called canonical variables. The treatment groups, therefore, may be further distinguished by evaluating these canonical variables. Analysis of canonical discriminant functions indicates that the main influence for the differences of cost input intensities in the three countries can be determined by the eigenvalue coefficient of CAN1, where $X > 0$ denotes that fingerling input intensity continually grew larger and $X < 0$ denotes that feed input intensity became smaller. Figure 5 shows that the Chinese farms are distributed in an area of high feed input intensity; four farms from the Vietnamese farms are distributed in an area of fingerling and other input intensity. Overall, farms from Vietnam are distributed in an area near the origin, namely the input intensity in Vietnam has insignificant single expenditure. Farms in Taiwan are distributed dispersedly, and four farms fall into an area of fingerling and labor input intensity in quadrant I. Two farms fall into an area of fingerling and other input intensity in quadrant IV, which is related to the different sizes of fingerlings and the survival rate of farms.

To sum up, this study discusses the possible factors affecting the differences in cost input intensities in different countries. First, the difference in feed input intensity is related to stocking density, survival rates, and feed types of the farms. Stocking density and survival rate may have direct influence upon feed input quantity. High stocking density and high survival rates may result in increased feed input, which increases feed input costs. These biological data, gathered from farms, indicate that stocking density and survival rate is highest in China (Table 5), and thus, the feed input quantity is greater. In Taiwan, the stocking density is similar to that of China; however, the survival rate is lower, and accordingly, the feed expenditure is relatively lower. For feed input, farmers in Vietnam use trash fish due to a lack of artificial feed and a low cost of trash fish. However, trash fish is seasonal, and the farmers often must buy trash fish during the production season and rent cold storage for storage. Thus, the stock–sales ratio is increased, and the flow of capital is reduced accordingly. China and Taiwan use artificial feed and trash fish feeding methods, which farmers choose according to their farming conditions, such as source and unit price of trash fishes, prices, quality of feeds, and supplier needs (some suppliers may request the farmers to use feed to ensure stable quality). Regarding fingerling cost input, Taiwan has the highest fingerling cost intensity among the three countries, which is related to the unit price of fingerling, high stocking density, and lower survival rates. The unit price of fingerlings is $27 TWD, per fingerling, in Taiwan, $18 TWD in Vietnam, and $5 TWD in China. In Penghu, Taiwan, due to the higher latitude, the northeast winter monsoons often cause a lower water temperature, which is adverse to cobia growth (Huang et al. 2002; Liao et al. 2004; Miao et al. 2009). As a result, some cobia farmers may buy winter fingerling of a larger size, which they stock in January and February and then harvest before winter in order to reduce losses caused by chilling injury (Huang et al. 2002; Shyu and Liao 2004; Kenneth et al. 2007).

Profitability analysis results indicate that China has the highest total revenue of 4319.76 TWD/m^3 per unit culture water. However, for the net revenue, Taiwan has the highest profitability, with a net revenue of 1180.93 TWD/m^3. Taiwan has the best benefit–cost ratio, at 1.63, which means $1.63 TWD can be gained at every one Taiwan dollar input. Overall, cobia cage cultures in Taiwan, China, and Vietnam have good economic performance. For the 22 farmers surveyed in this study, their benefit–cost ratio ranged from 1.10 to 2.24. In addition, we can understand the influence of costs on production, for example, high feed profitability indicates that the farms have good feeding management and high fingerling profitability, meaning good quality of fingerling. Analysis of individual profitabilities indicates that feed and fingerling profitability in Taiwan averaged 0.78 and 10.26, respectively (Table 3), reflecting improved performance, and regional profitability has significant difference ($\alpha < 0.05$) (Table 6), as based on MANOVA result.

The profitability of discriminant function analysis shows that eigenvalue for CAN3 is highest and statistically significant. The higher score of CAN3 indicates that the corresponding farms have higher feed profitability. On the contrary, any farm that has a less fingerling profitability may have a much smaller score of CAN3 (Table 10, Fig. 6). From the distribution of cobia farms on the two canonical variables, as computed by profitability variables (Fig. 6), Taiwanese farms are concentrated in the feed profitability indices and Vietnamese profitability ranged between the two countries. For China, the fingerling profitability affects total profitability and is significant. Feed costs account for more than 85% of the total cost of cobia farming. Thus, feeding management can directly affect the total economic performance. The quality, price, and input management of feed in Taiwan could serve as reference for other countries to increase their feed profitability. China has better fingerling profitability, which is related to the lower unit price and higher survival rate. Cobia fingerling in Vietnam relies on exports from Taiwan, and cobia fingerling in China is supplied by a local propagator; thus, the fingerling price has an advantage, compared to Vietnam. Hence, China's fingerling profitability has an advantage over Taiwan and Vietnam. In addition, Fig. 6 points out that one of the Chinese farms (at the far left of CAN3 axis) has a best performance in fingerling profitability. In the future, we can investigate this farm and find out their source of fingerling and management style, which can be used as a reference to other farms to improve their fingerling profitability.

Since the 1990s, Taiwan has fostered a cobia commercial culture. Due to limitations of natural conditions and costs, some farmers selected the Southeast Asian regions to invest in cobia farming, of which Vietnam is the one of the regions. According to the data collected by questionnaire survey, there are nine studied farms in Vietnam that have Taiwanese investment, while the scale of cobia-farming investment by the local people is small. Although Taiwan and Vietnam have different farming conditions, the operating management styles of the farms are similar. Therefore, Taiwan and Vietnam have similarities in cost input and profitability (Tables 7 and 9). However, the cobia produced in Vietnam has no domestic market; hence, the prices of adult fish are determined by the shippers. According to the data collected by this study, differences in unit prices in Taiwan and Vietnam are 20–30 TWD, which is one of the main reasons for the different ratios of net profit to total cost in Taiwan and Vietnam. According to the data collected in this study, China has high stocking density (Table 5) and the highest feed input intensity (Table 1), its benefit–cost ratio ranks last (Table 4), and feed profitability is also lower (Table 3). Hence, China may improve feed quality and feeding management to improve its profitability. Moreover, China's fingerling profitability is the highest among the three countries, which is related to lower prices, good quality, and high survival rates of the fingerling. China actively conducts studies of cobia fingerling while developing its cobia cage culture (Zhou et al. 2004, 2006, 2007; Sun et al. 2006a, 2006b). Moreover, the average water temperature in Hainan is more than 20°C, which can extend spawning time. Quantity and quality are the reasons for improved fingerling profitability in China. At present, cobia fingerling cultured by China is supplied to local farmers and exported to other countries, including Taiwan and Vietnam.

Regarding cobia farming in Taiwan, the unit price is 20 TWD/kg higher than that of China and Vietnam (Table 2); however, Taiwan uses quality difference to increase its advantage in international market price negotiations in order to offset the high costs. Feed profitability of Taiwan shows the best performance in this study, which is due to the development of feed. Sources of trash fish are not stable; thus, feed input quantity is difficult to determine. The farmers prefer to choose artificial feed in order to ensure the quality of cobia, which promotes research and development for quality cobia feed. Taiwan developed cobia farming very early, and many studies have focused on cobia. In 2007, ten experts, led by Fan-Hua Nan, PhD, compiled the Handbook of Cobia, as based on their respective study fields. This book involves fingerling, feed, disease, processing, operations management, farming systems, hardware facilities, etc. With the establishment of aquaculture farm food safety certification systems, such as HACCP and GAP, and the promotion of aquatic product records and electronic management, Taiwan will have stronger competitiveness in international markets (Nan 2007).

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