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Farm-level returns and costs of yellow catfish (*Pelteobagrus fulvidraco*) aquaculture in Guangdong and Zhejiang provinces, China

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ABSTRACT

Freshwater aquaculture in China is expanding and intensifying as this country experiences rapid economic growth, and understanding farm-level profitability is necessary if farmers are to make reasonable decisions about their production plans. We conducted a survey of yellow catfish farmers in 2014 in Guangdong and Zhejiang provinces in order to estimate farm-level profitability of pond aquaculture. We selected representative prefectures from the 2 provinces as study areas and used convenience sampling. Eighty-seven farmers were interviewed between April and May 2014 and the questionnaire collected detailed information on: (1) farmers' demographics (age, gender, education, training, and experience); (2) production inputs (land, labor, fingerlings, feed, chemicals, machinery, and other miscellaneous costs); and (3) outputs (weight and revenue of harvested fish). Responses of 61 farmers included in the data analysis were post-stratified into 3 categories of farm size (<1.47 ha, 1.47–3.67 ha, and >3.67 ha). We calculated production cost components, returns, and returns-costs ratios by farm size in each province. The overall returns-costs ratio was 1.31 in Guangdong and 1.17 in Zhejiang. Farmers in Guangdong invested more in land and machinery and had higher percentages of labor costs and chemical expenditures, but achieved better returns-costs ratios than farmers in Zhejiang. Higher land rent might be associated with greater yields of yellow catfish in Guangdong, which were almost twice those of Zhejiang.

1. Introduction

Freshwater finfish aquaculture has expanded in mainland China during the last 20 years, and China now leads globally in production and consumption of farmed freshwater species (Chiu et al., 2013; FAO, 2014). Approximately 70% of freshwater aquaculture production in China is carried out in ponds (Wang et al., 2014), and its development has been influenced by production inputs, including land, or availability of water, fish diseases, and farmers' knowledge and practices (Ahmed et al., 2007). Thus it is necessary to assess the degree to which their farm-level production inputs are cost-effective for farmers to make decisions on production expansion.

Several Chinese economic studies have evaluated profitability (Chen, 2008; Yuan and Xun, 2009), production function (Chen, 2010), production efficiency (Gao et al., 2012), and cost efficiency (Liu, 2007) of freshwater fish farmers. However, few studies have focused on analyses of returns and costs of freshwater pond aquaculture in China (Chen et al., 1995; Gomiero et al., 1997; Yuan, 2007; Yin et al., 2014). Furthermore, surveyed data were seldom used to examine the extent of input usage in freshwater fish farms in China (Yin et al., 2014). Survey studies are necessary to investigate the current profitability of Chinese freshwater fish farmers.

One native freshwater species that has a strong market demand is yellow catfish (*Pelteobagrus fulvidraco*), commonly called yellow bonefish by farmers in southern and eastern China (Dong et al., 2011; Liu et al., 2013). Production of yellow catfish has expanded because of widespread availability of fry, innovative feed technology, the species' tolerance for long distance transportation, and its high market value (Tan et al., 2012; Tang et al., 2012). It has now become one of the most important freshwater finfish species in Chinese aquaculture (Wu et al., 2010; Dong et al., 2011). To our knowledge, there are no recently published studies in English using survey data to examine farm-level profitability of pond-based yellow catfish aquaculture in China. The objective of our study was to estimate returns and costs for yellow catfish aquaculture in China at the farm level.

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Table 1
Source population and sample size of yellow catfish farms investigated in Guangdong and Zhejiang provinces in 2014. Percentages are provided in brackets.

Province	Prefecture	County	Estimated number of farms in each county	Total number of farmers interviewed	Total number of farms analyzed
Guangdong	Foshan	Nanhai	3,000	44	33
Zhejiang	Huzhou	Deqing	800	10	8
		Nanxun	1,000	19	10
		Wuxing	1,000	14	10

2. Material and methods

2.1. Sampling design for yellow catfish farms

We carried out a survey in 2014 on yellow catfish farms in 2 major freshwater aquaculture provinces, Zhejiang and Guangdong, in China. According to field staff working for one of the largest fish feed-companies in Zhejiang province, Guangdong province has the highest yield of yellow catfish in China, while Zhejiang province is one of the provinces with the longest history of inland freshwater aquaculture.

Foshan prefecture, in Guangdong province, supports 80% of yellow catfish production in that province, and has 3333–4000 ha of pond culture of yellow catfish (Su, 2015). We selected Nanhai County in Foshan because it has the largest yellow catfish production among the 5 counties in this prefecture (Yin, 2015). Huzhou is the major prefecture for freshwater aquaculture in Zhejiang province, and has 3333–4667 ha of aquaculture ponds (Yin, 2015). Three counties in Huzhou were included in the sampling: Deqing, Nanxun, and Wuxing. Foshan and Huzhou are prefecture-level cities, ranked below a province and above a county in China's administrative structure.

The sample sizes were proportional to the estimated number of yellow catfish farms in the study areas, as shown in Table 1. Estimation of total number of yellow catfish farms in each county was based on the anecdotal notes of aquatic experts, feed-company sales representatives and local fish veterinarians. We have interviewed 44 farmers in Guangdong and 43 in Zhejiang during April and May 2014.

2.2. Data collection and data entry

A structured interview was used for data collection in both provinces, and consisted of 3 parts: demographic information, input and output quantities and prices, and biosecurity practices/behavior. Confidentiality protection was first explained to respondents, and interviews were only conducted after farmers' consent. The farmers were interviewed, where we could meet them, either on their own fish farms, at aquatic service stations owned by industry middlemen or at private fish vet clinics. Visits to the farmers were done in the company of field staff working for aquatic feed companies. The interviewer took notes when respondents' answers were outside the range of choices in the questionnaire or when respondents provided additional anecdotal information. The average yellow catfish production cycle was assumed to be no more than 12 months' duration, with stocking after January 2013 and harvesting before May 2014, which was the last production cycle before the survey. Original survey data were entered into Excel, and each farmer was assigned an identification number to ensure confidentiality. All non-responses were kept blank.

2.3. Post-stratification for surveyed farms

Different methods of using covariate variables have been developed for deciding optimum stratification boundaries to reduce the potential error of misclassification (Singh and Sukhatme, 1969; Singh, 1971; Mahajan and Singh, 2005; Khan et al., 2009a; Sebnem, 2011). In this study, farm size was used as the covariate for the post-stratification process. All 87 yellow catfish farms were categorized into 3 classes, using the cube-root cumulative-frequency method, as in Eq. (1) (Singh and Mangat, 1996; Shyamalie, 2008). In brief, 2-class post-stratification was found to mix farms of medium and large sizes, and was a less efficient distribution of farms than the 3-class stratification method. Thus, 3-class stratification was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).

$$L_i = y_{i-1} + \left[\left(S_k/L - S_{i-1} \right) / \sqrt[3]{f_i} \right] (y_i - y_{i-1}) \quad (1)$$

Where;
L = No. of strata;
L_i = Upper limit of i th stratum;
y_{i-1} = Lower limit of the class in which L_i lies;
$\sqrt[3]{f_i}$ = Cube root of the frequency of the i th class in which L_i lies;
S_k = Cumulative total of $\sqrt[3]{f_i}$;
S_{i-1} = Cumulative cube root of the frequency of preceding class to the class in which L_i lies;
y_i = Upper limit of the class in which L_i lies;
$y_i - y_{i-1}$ = Width of the class in which L_i lies.

2.4. Descriptive analysis of demographic data and production profiles of study farms

We summarized relevant demographic information of farmers, including gender, age, education background, and aquaculture experience and related professional training. We also conducted descriptive analysis of farm size, characteristics of ponds used for adult fish (pond area, pond size, and pond number), land rent price, harvested biomass, fish yield and feed usage. Apparent feed conversion ratio (AFCR), an appropriate approach for assessing aquafeed utilization efficiencies of carnivorous species (FAO, 1987; FAO, 2002), was estimated by farm size categories.

2.5. Returns and costs analyses

The farm-level economics of yellow catfish aquaculture was evaluated using returns and costs analysis (Lipton and Harrell, 1990). In order to increase the accuracy of the production and harvest information, farm data were excluded if harvests were partial, or were full but with incomplete information. All descriptive analyses of survey data were performed using STATA 13 (Stata Corp., College Station, TX, USA). We used the following standard terms for costs and returns.

2.5.1. Total fixed costs

Fixed costs are those that are not altered by a change in the level of production (Lipton and Harrell, 1990). Total fixed costs included depreciation of medium- and long-term capital, opportunity cost of using medium- and long-term capital, land rent, land revenue in case of owned land, and wages for permanent labor.

Total medium- and long-term capital referred to the capital used for more than one production cycle. Total medium- and long-term capital included expenditures on machines and other equipment related to aquaculture management, including oxygenators, power generators, harvest nets, feed mixers, and water pumps.

Opportunity cost of using medium- and long-term capital. We assumed that the next best alternative for using medium-and-long term capital was a long-term deposit in the bank. This opportunity cost was calculated as interest forgone for 12 months, using a 60-month deposit rate of 4.75% per annum, as per the Bank of China (Bank of China, 2012).

Depreciation of medium- and long-term capital is the decline over time in the value of capital, primarily due to wear and tear. Based on an assumption of predicted (approximately constant) depreciation, the straight-line method of depreciation was applied, by dividing purchase value at current prices by economic life (in years). The economic life of different farm equipment was assumed, on average, to be: 5 years for oxygenators and feed mixers, 10 years for water pumps, and 15 years for diesel generators and harvest nets.

Land rent was the product of land rent per hectare and farm size. Land in the study areas was generally owned by the villages, and farmers paid rent to the village-level government.

2.5.2. Total variable costs (TVC)

Variable inputs were those that change with levels of production (Lipton and Harrell, 1990). The expenditure associated with variable inputs was called short-term capital. TVC was the sum of short-term capital and opportunity cost of using short-term capital.

2.5.2.1. Total short-term capital. Total short-term capital included expenditures on fingerlings, feed, chemicals, wages of casual/seasonal hired labor, imputed value of part-time family labor, electricity, pond sediment removal, pond disinfection before stocking, and farm equipment repairs.

Feed expenditure referred only to expenditures incurred for supplementary feed, and excluded natural feed found in ponds (i.e. plants). If different supplementary feeds were used on a farm, feed expenditure was calculated as the sum of the expenditures of those different feeds. Single feed cost was calculated as feed price per 1000 kg multiplied by usage.

Chemical expenditure referred to expenditures on all chemicals and biological fertilizers, including antibiotics, anti-parasitics, and other medicines for treatments, water improvement detergents, and other chemotherapeutics related to fish health improvement.

Casual/seasonal hired labor cost included wages for full-time seasonal staff and for casual labor hired only for harvesting fish and seining ponds.

Family labor wages were imputed as total number of months of family members working on a farm, either full-time or part-time, multiplied by average monthly income for farmers in the 2 prefectures. Annual income was reported to be USD 2823 and USD 3,071 for rural residents in the prefectures of Huzhou (Baidu, 2014) and Foshan (Wu, 2014), respectively.

2.5.2.2. Opportunity cost of short-term capital. We assumed that the next best alternative for using short-term capital was a short-term deposit in the bank; therefore, opportunity cost was the foregone interest. Opportunity cost of short-term capital was calculated by multiplying total short-term capital for 6 months by a 3-month deposit rate of 2.85% per annum, as per the Bank of China (Bank of China, 2012). It was difficult to calculate the distribution of the use of short-term capital over the year and within a particular month; therefore, we assumed that farmers used equal proportions of short-term capital in the middle of every month.

2.5.3. Gross return

Gross return was the total monetary receipt generated by sales of all harvested fish (Yuan, 2007). Farm-level gross return was computed by multiplying total weight of harvested fish (kg) by market price (USD/kg).

2.5.4. Net return

We used 3 different measures for net return in this study, as follows:

Net return over total cost (Net return OTC) was computed as gross return minus total costs. In the long run, net return OTC must be positive for the farm to be economically viable.

Net return over variable cost (Net return OVC) was calculated by subtracting total variable costs from gross return. Farmers must cover total variable costs in the short term to remain economically viable, i.e., Net return OVC should be positive.

Net return to family labor (Net return TFL) was calculated by taking Net return OVC and adding the opportunity costs of family labor, which were the imputed wages. Off-farm work alternatives to aquaculture might be very few or only seasonal available for these fish farmers in the 2 provinces. By assuming that family labor used on the farm was a forgone cost, the imputed wages were approximated as the values of unpaid family labor (Engle, 2010). Except unpaid family labor, other opportunity costs of investing family labor are negligible in this study. In the short term, a net return TFL is an appropriate measure to evaluate the economic viability.

2.5.5. Returns-costs ratio and other indicators of farm-level profitability

Calculations for the returns-costs ratio and other economic indicators were done for different farm sizes in the 2 provinces.

3. Results

Data from 61 of 87 (70.1%) sampled farms (with fully-harvested fish before the end of the survey and with complete production information) were included in the descriptive analysis. Demographic information was summarized by province. Production and returns-costs analyses were evaluated and reported, based on post-stratified farm-size groups for each province.

3.1. Demographic information

Among the 61 yellow catfish farmers interviewed, there was only one female respondent in Guangdong, and no female respondents in Zhejiang (Table 2). The mean ages of farmers were 53 (range, 30–65) and 50 (range, 25–65) for Guangdong and Zhejiang, respectively. Forty-four percent of farmers in Guangdong were in the age group ranging from 55 to 65 years, while 71% of farmers in Zhejiang were within the age group of 41–55 years.

Most yellow catfish farmers in both provinces had elementary school education. In Guangdong, 12% of farmers had not completed elementary school. A slightly higher percentage (26%) of middle school was reported in Zhejiang province. One farmer (4%) in Zhejiang had a college education.

Aquaculture experience was defined as the number of years that a farmer had been involved in any form of aquaculture production, and was not confined to yellow catfish culture, which was encouraged in the study areas starting in about 2002. Prior to 2002, most farmers in both provinces were involved in carp production. In this study, farmers in Guangdong and Zhejiang averaged 16–18 years'

Table 2
Demographic information of yellow catfish farmers in Guangdong and Zhejiang provinces in 2014. Percentages are provided in brackets.

Variables	Guangdong		Zhejiang	
	Response rate (%)	Number	Response rate (%)	Number
Gender	100	33	100	28
Female		1 (3)		0
Male		32 (97)		28 (100)
Age (years)	94	32	100	28
25–40		4 (13)		2 (7)
41–55		13 (41)		20 (71)
56–65		14 (44)		6 (21)
Education	100	33	96	27
Below elementary		4 (12)		0
Elementary		21 (64)		18 (67)
Middle school		5 (15)		7 (26)
High school		3 (9)		1 (4)
College		0		1 (4)
Aquaculture experience (years)	100	33	100	28
1–5		4 (12)		2 (7)
6–10		10 (31)		5 (18)
11–15		3 (9)		5 (18)
16–20		8 (24)		7 (25)
21–35		8 (24)		9 (32)
Exposure to aquaculture training	100	33	96	27
With training		2 (6)		6 (22)
Without training		31 (94)		21 (78)

experience in the industry (Table 2). Interestingly, 30% of respondents in Guangdong had 6–10 years of experience, and might not have had any experience with freshwater aquaculture before they started growing yellow catfish. The highest percentage (32%) of farmers reporting the most experience (21–25 years) was in Zhejiang. For each province, almost 50% of farmers had more than 15 years of experience. Only 6% and 22% of farmers in Guangdong and Zhejiang provinces, respectively, reported having formal aquaculture training.

3.2. Production systems

3.2.1. Farm size, biomass harvested and yellow catfish yield

Mean farm sizes were 0.7 ha and 2.1 ha for Guangdong and Zhejiang provinces, respectively (Table 3). Most farms in Guangdong were small, belonging to category I (< 1.47 ha), which decreased the mean value of farm size for this province. In contrast, almost 50% of farms in Zhejiang belonged to the 2 upper strata of farm sizes (1.47–3.67 ha and ≥3.67 ha).

Farmers in Zheijang tended to have larger single pond sizes and larger farm sizes, total area of ponds per farm and total number of adult ponds per farm (Table 3). Farms in Guangdong had, on average, smaller fish ponds (0.36 ha/pond) than those in Zhejiang (0.65 ha/pond). The biggest average pond size of 0.82 ha was in the category III farms in Zhejiang, which was almost twice the average pond size of farms in Guangdong (Table 3). The maximum total number of ponds (14 ponds per farm) was also reported from the category III farms in Zhejiang, compared with at most 4 ponds per farm in Guangdong. The average land rent per hectare in Guangdong (USD 6,034) was almost 3-fold higher than in Zhejiang (USD 2,109), which reflected a geographical difference in land costs and land allocations between and within provinces (Table 3).

The total biomass harvested per farm in category I was 16.1 t and 13.1 t for Guangdong and Zhejiang, respectively (Table 3). Farms in Guangdong had higher average biomass harvested per hectare (27.6 t/ha) than those in Zhejiang (16.3 t/ha). The average biomass per unit of land was similar among farms in the 2 farm-size categories in Guangdong. However, this was not the case in Zhejiang, where category III farms produced on average 18.4 t of fish per hectare, while 16.7 t per hectare was reported from category I, and 14.8 t per hectare from category II farms in that province.

The average yield of fish in Guangdong (25.68 t/ha) was more than twice that of Zhejiang (14.59 t/ha) (Table 4). The lowest yellow catfish yield (7.75 t/ha) was in category II farms in Zhejiang,

Table 3
Farm size, pond area, pond size, pond number, land rent per hectare and harvested fish of yellow catfish farms in Guangdong and Zhejiang provinces in 2014. n = number of farmers.

Variables	Guangdong			Zhejiang			
	Category I[a] (n = 31)	Category II[a] (n = 2)	Overall (n = 33)	Category I[a] (n = 15)	Category II[a] (n = 9)	Category III[a] (n = 4)	Overall (n = 28)
Mean area of farm (ha)	0.63	2.50	0.74	0.74	2.01	7.18	2.07
Mean area of adult pond per farm (ha)	0.55	1.93	0.64	0.73	1.79	5.94	1.81
Mean water surface area per adult pond studied (ha)	0.35	0.48	0.36	0.55	0.76	0.82	0.65
Mean land rent per hectare (USD/ha)	6,040	5,927	6,034	2,232	2,105	1,730	2,119
Median and range of total number of adult ponds studied per farm	1 (1–3)	4 (4–4)	4 (1–4)	1(1–4)	2 (1–6)	6 (4–14)	2 (1–14)
Mean total biomass harvested per farm (ton)	16.1	49.3	18.1	13.1	23.9	96.6	28.5
Mean biomass per hectare harvested (ton/ha)	27.6	27.2	27.6	16.7	14.8	18.4	16.3
Mean fish production[b] (kg)	14,723	48,650	18,545	12,098	20,497	86,099	25,369

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).
[b] Fish production is the net biomass gain of the production cycle (total biomass harvested minus total initial biomass).

Table 4
Fish yield (1000 kg/ha) of yellow catfish farms in Guangdong and Zhejiang provinces in 2014. n = number of farmers.

Variables	Guangdong			Zhejiang			
	Category I[a] (n = 31)	Category II[a] (n = 2)	Overall (n = 33)	Category I[a] (n = 15)	Category II[a] (n = 9)	Category III[a] (n = 4)	Overall (n = 28)
Average yield of all fish	25.65	26.87	25.68	15.25	12.70	16.40	14.59
Yield of yellow catfish	25.65	26.87	25.68	13.99	7.75	13.92	11.98
Yield of black carp					1.43		0.46
Yield of white carp				1.37	3.09	2.48	2.08
Yield of other fish					0.45		0.14

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).

Table 5
Commercial feed and crude protein input of yellow catfish farms in Guangdong and Zhejiang provinces in 2014. n = number of farmers.

Variables	Guangdong			Zhejiang			
	Category I[a] (n = 31)	Category II[a] (n = 2)	Overall (n = 33)	Category I[a] (n = 15)	Category II[a] (n = 9)	Category III[a] (n = 4)	Overall (n = 28)
Commercial feed							
Total commercial feed usage (1000 kg)	25.96	73.50	28.84	19.19	31.20	119.75	37.41
Commercial feed usage per area (1000 kg/ha)	45.29	39.78	44.95	24.60	18.48	24.36	22.59
Crude protein input							
Total crude protein input (1000 kg)	10.05	28.73	11.18	7.69	12.62	33.41	12.95
Crude protein per area (1000 kg/ha)	17.34	15.62	17.23	9.86	7.43	7.61	8.76
Apparent feed conversion ratio							
AFCR (Feed usage/fish production)[b]	1.83	1.55	1.81	1.56	1.57	1.42	1.55

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).
[b] Fish production is the net biomass gain of the production cycle (equal to total biomass harvested minus total initial biomass).

among which the same type of farms had mixed species farming and polyculture of yellow catfish (Table 4). Mixed species farming of yellow catfish occurs when a farmer produces yellow catfish and other freshwater fish in different ponds on the same farm. Polyculture is when yellow catfish are raised with other species in the same pond. Fish farmers in Zhejiang province had a higher proportion of culture combinations, with 61% practicing monoculture and 39% farming polyculture or mixed species. White carp (*Erythroculter ilishaeformis*) was the species usually stocked with yellow catfish in polyculture operations. Black carp (*Mylopharyngodon piceus*) and yellow catfish (*Pelteobagrus fulvidraco)* were cultured in different ponds from yellow catfish farms in category II farms in Zhejiang Province (Table 4). However, in Guangdong province, most farmers (97%) kept yellow catfish in monoculture on the same farm, and only 3% of farmers practiced mixed-species farming and there was negligible yield information for the different species in polyculture.

3.2.2. Feed brand choices, feed usage, and crude protein input

Two different types of domestic fish feed companies (local and non-local) supply farms. We differentiated them based on production scales and marketing strategies. Interestingly, 88% of farmers in Guangdong chose non-local companies, while in Zhejiang almost equal percentages of farmers chose non-local (57%) and local companies (43%). Most category I farms in Guangdong chose non-local companies, while among farms in the same category in Zhejiang, the number of farms choosing non-local feed companies was 1.5 times greater than those choosing local feed companies.

In this study, the feed input for yellow catfish farms in Guangdong was 44.95 t per hectare, while for farms in Zhejiang it was 22.59 t per hectare (Table 5). Crude protein usage in the 2 provinces showed a similar difference. Farms in Guangdong had an overall higher estimated apparent feed conversion ratio (AFCR) (Table 5). The average AFCRs of farms in Guangdong: 1.83 for category I, and 1.55 for catergory II. In contrast, there was no apparent variation of AFCRs among different types of farms in Zhejiang.

3.3. Returns and costs analysis

3.3.1. Capital requirements and costs

Costs varied among different types of farms in the 2 provinces; for example, total fixed costs ranged from 4.6% to 10.1%, and total variable costs ranged from 90.2% to 95.3% (Table 7). Extreme values of the cost components were found in category II farms in Guangdong and category III farms in Zhejiang. Farmers in Guangdong invested less short-term capital than those in Zhejiang while, in contrast, the amount of medium- and long-term capital invested in Guangdong was higher than in Zhejiang.

3.3.1.1. Total fixed cost. Medium- and long-term capital in Guangdong (USD 2492) was about 2-fold higher than in Zhejiang (USD 1401) (Table 6). Farmers in Zhejiang invested 91.1% of their medium- and long-term capital on oxygenators (Table 6), while machinery investments by farmers in Guangdong included other aquaculture equipment, i.e. diesel generators, harvest nets, feed mixers, and water pumps.

Differences in total fixed cost components, particularly land rent percentages, existed among farms in the 2 provinces (Table 6), while the overall percentage of land cost of farms in Guangdong was 50% higher than in Zhejiang. Farmers in Zhejiang reported reduced production costs by not investing in aquaculture equipment, such as harvest nets, feed mixers, and water pumps. Furthermore, the percentage differences of depreciation of medium- and long-term capital between the 2 provinces were directly related to total medium- and long-term capital investments. Farmers in Categories I and II in Guangdong reported larger investments in aquatic machinery than farms in the same categories in Zhejiang.

3.3.1.2. Total variable cost. Total variable cost as a percentage of total cost was 94.8% in Zhejiang and 91.4% in Guangdong (Table 7). Compared with medium- and long-term capital requirements, the short-term capital requirement was responsible for the majority of total costs, 90.7% in Guangdong and 93.5% in Zhejiang. Among all components of total short-term capital of farms in both provinces,

Table 6
Capital requirements of yellow catfish farms in Guangdong and Zhejiang provinces in 2014. n = number of farmers (currency in USD).

	Guangdong						Zhejiang							
	Category I[a] (n = 31)		Category II[a] (n = 2)		Overall (n = 33)		Category I[a] (n = 15)		Category II[a] (n = 9)		Category III[a] (n = 4)		Overall (n = 28)	
Variables	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
I. Total medium- and long-term capital	2,244	100	5,516	100	2,492	100	688	100	1,037	100	4,906	100	1,401	100
i. Oxygenator	1,131	50.4	3,339	61	1,265	50.8	623	90.6	951	91.7	4,462	90.9	1,276	91.1
ii. Diesel generator	312	13.9	645	12	332	13.3	65	9.4	86	8.3	363	7.4	114	8.1
iii. Harvest net	47	2.1			44	1.8					81	1.7	11	0.8
iv. Feed mixer	83	3.7			78	3.1								
v. Water pump	671	29.9	1,532	28	773	31								
II. Total short-term capital	44,084	100	120,411	100	48,710	100	33,671	100	59,254	100	250,980	100	72,938	100
i. Fingerling expenditure	3,457	7.8	5,806	4.8	3,599	7.3	3,592	10.7	8,043	13.6	41,352	16.5	10,417	14.3
ii. Feed expenditure	31,857	72.3	83,226	69.1	34,970	71.8	25,110	74.6	42,228	71.3	186,786	74.4	53,709	73.6
iii. Chemical expenditure	1,541	3.5	7,742	6.4	1,917	3.9	773	2.3	2,428	4.1	4,726	1.9	1,870	2.6
iv. Hired labor wages	827	1.9	2,258	1.9	914	1.9	419	1.2	735	1.2	4,839	1.9	1,152	1.6
v. Imputed value of family labor	3,278	7.4	3,999	3.4	3,322	6.8	3,072	9.1	3,413	5.8	4,607	1.8	3,401	4.7
vi. Other short-term expenditure	3,124	7.1	17,379	14.4	3,988	8.2	705	2.1	2,407	4	8,669	3.5	2,390	3.3
(1) Electricity	3,089	7.0	17,379	14.4	3,956	8.1	694	2.06	1,864	3.1	7,822	3.17	2,088	2.9
(2) Pond bottom mud removal	34	0.1			32				502	0.83			162	0.2
(3) Pond bottom disinfection							12	0.04	41	0.07	565	0.22	100	0.1
(4) Farm equipment amending											282	0.11	40	0.1

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).

Table 7
Costs associated with yellow catfish farming in two Guangdong and Zhejiang provinces in 2014. n = number of farmers (currency in USD).

	Guangdong						Zhejiang							
	Category I[a] (n = 31)		Category II[a] (n = 2)		Overall (n = 33)		Category I[a] (n = 15)		Category II[a] (n = 9)		Category III[a] (n = 4)		Overall (n = 28)	
Variables	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
I. Total fixed cost	4,064	8.3	13,663	10.1	4,648	8.6	1,832	5.1	4,143	6.4	12,279	4.6	4,067	5.2
i. Opportunity cost of using medium- and long-term capital	107	0.2	262	0.2	118	0.2	33	0.1	49	0.1	233	0.1	67	0.1
ii. Depreciation on medium- and long-term capital	221	0.5	530	0.4	240	0.4	67	0.2	101	0.2	476	0.2	136	0.2
iii. Land rent	3,736	7.6	12,871	9.5	4,290	8	1,732	4.8	3,993	6.1	11,570	4.3	3,864	4.9
II. Total variable cost	44,712	91.7	122,127	89.9	49,404	91.4	34,151	94.9	60,099	93.6	254,556	95.4	73,977	94.8
i. Total short-term capital	44,084	90.4	120,411	88.7	48,710	90.1	33,671	93.6	59,254	92.3	250,980	94.1	72,938	93.5
ii. Opportunity cost using short-term capital	628	1.3	1,716	1.3	694	1.3	480	1.3	845	1.3	3,576	1.3	1,039	1.3
III. Total cost (I + II)	48,776	100	135,790	100	54,052	100	35,982	100	64,242	100	266,835	100	78,044	100

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47 − 3.67 ha), and category III (> 3.67 ha).

feed cost was the highest of all single item costs listed, ranging from 69.1% to 74.6%. Farmers in both provinces shared similar percentages of chemical expenditures, hired labor and family labor. However, the average percentage for fingerling costs in total short-term capital in Zhejiang was almost twice as that in Guangdong. The electricity cost of farms in Guangdong was 8.1% of total short-term capital, compared with 2.9% for farms in Zhejiang.

3.3.2. *Returns and returns-costs ratios*

The average gross return in Zhejiang was USD 91,698, compared with USD 70,716 in Guangdong, but this was skewed by the large category III farms in Zhejiang (Table 8). On average, farms in category I in Guangdong achieved a gross return of USD 62,243, while the gross return for the same size category in Zhejiang was USD 43,843 (Table 8).

Farmers in Guangdong had a higher overall average value for all 3 measures of net return than those in Zhejiang (Table 8). These were: net return over total costs, net return over total variable costs, and net return to family labor.

Overall returns-costs ratios for Guangdong and Zhejiang were 1.31 and 1.17, respectively, while the estimated average cost per harvest biomass (USD/kg) was numerically higher in Guangdong (Table 8). The average cost per hectare in Guangdong (USD 73,043) was more than twice than that in Zhejiang (USD 37,703) (Table 8).

After we calculated net return per harvest fish weight, we also found a difference of net return per kg of USD 0.44 between farms in Guangdong and Zhejiang (Table 8). The net return per ha of farms in Guangdong was also numerically higher than those in Zhejiang, with farmers in Guangdong receiving more than twice the net return per hectare of farmers in Zhejiang.

4. Discussion

Our returns and costs analyses showed that the lowest net returns per kg of harvested fish were obtained for farms of category III in Zhejiang and the highest were from in category II farms in Guangdong. Although total costs per kg were much lower, on average, for similar sized farms in Zhejiang, gross returns were higher on farms in Guangdong province. In general, farmers in Guangdong had higher net returns than those in similar size categories in Zhejiang. When we compared category I farms, net return in Guangdong was two-fold higher than that of Zhejiang. Category II farms in Guangdong had the highest net return per harvest biomass (USD 1.34/kg). If the family labor was excluded from short-term capital, farmers in Guangdong realized net return at almost 2.5 times higher than farmers in Zhejiang.

One possible explanation why farmers in Guangdong had a higher gross return than similar sized farms in Zhejiang was that

Table 8
Returns from yellow catfish farms in Guangdong and Zhejiang provinces in 2014. n = number of farmers (currency in USD).

Variables	Guangdong			Zhejiang			
	Category I[a](n = 31)	Category II[a] (n = 2)	Overall (n = 33)	Category I[a](n = 15)	Category II[a](n = 9)	Category III[a] (n = 4)	Overall (n = 28)
I. Gross return	62,243	202,048	70,716	43,843	75,044	308,623	91,698
II. Net return (gross return − total costs)	13,467	66,258	16,664	7861	10,802	41,788	13,654
III. Net return over variable cost (gross returns − total variable costs)	17,531	79,922	21,312	9,692	14,945	54,067	17,720
IV. Net return to family labor (III + imputed value of family labor[b])	20,809	83,921	24,634	12,764	18,358	58,674	21,121
V. Returns-costs ratio (Gross returns/total costs)	1.28	1.49	1.31	1.22	1.17	1.16	1.17
VI. Other indicators of profitability							
i. Average cost per kg[c](Total cost/total harvested fish biomass)	3.03	2.75	2.99	2.75	2.69	2.76	2.74
ii. Average cost per ha (Total fixed cost + total variable cost)/total farm size	77,421	54,316	73,043	48,625	31,961	37,164	37,703
iii. Gross return per kg[c](Gross return/total weight of harvested fish biomass)	3.87	4.1	3.91	3.35	3.14	3.19	3.22
iv. Gross return per ha (Gross return/total farm size)	98,789	80,819	95,562	59,247	37,335	42,984	44,299
v. Net return per kg[c](Net return OVC/total harvested fish biomass)	0.84	1.34	0.92	0.6	0.45	0.43	0.48
vi. Net return per ha (Net return OVC/total farm size)	21,377	26,503	22,519	10,623	5,374	5,820	6,596
vii. Net return to family labor per ha (Net return to family labor/total farm size)	33,031	33,568	33,290	17,248	9,133	8,172	10,203

[a] Three-class stratification of yellow catfish farms was applied: category I (<1.47 ha), category II (1.47–3.67 ha), and category III (>3.67 ha).
[b] Family labor was the Variable v. in Section II.Total short-term capital of Table 6.
[c] Fish harvest biomass as denominators of i, iii and v in the returns-costs analyses was from Table 3.

they raised fish at much higher densities. High-density stocking may be used because land in that province was more expensive than in Zhejiang. Farmers in Guangzhou likely chose small farm sizes to avoid the high cost of land rent, but compensated by raising more fish per hectare of land. This trend in their business strategy is consistent with the negative relationship reported by Chen et al. (2011) between farm size and profitability.

We speculated that the success of “extremely” high density stocking of yellow catfish in Guangdong might be related to favorable weather conditions, the availability of genetic improvement breeding programs, land price pressures, and market demand. Guangdong is located close to the tropics, where the production cycle is shorter for yellow catfish, as it can be cultured almost year round, compared to Zhejiang. During our study period, high-density farming of this species appeared to benefit farmers in Guangdong, but it might also be a higher risk. In outbreaks of infectious disease, the higher the density of fish in a pond the higher the mortalities (Plumb, 1999), which could reduce gross return significantly.

The mean market price of yellow catfish for farmers in Guangdong was USD 3.94/kg compared with USD 3.47/kg in Zhejiang. Thus, in addition to high yield, farmers in Guangdong also were paid more for their fish. In China, live fish are preferred by consumers. The development of aquatic logistics companies that transport fish over long distances has made it possible to sell live freshwater fish in almost every provincial capital city in China, even though the transportation distance to northern and western China markets is more than 3000 km from Guangdong. This has opened significant markets for fish farmed in Guangdong. Seventy percent of yellow catfish in Guangdong were reported as transported to other provinces (according to anecdotal notes). In contrast, fish transport companies are not as well established in Zhejiang, and the markets for farmers in this province are limited to local and adjacent provinces.

Farmers in Zhejiang tended to practice multi-age stocking, polyculture and mixed species rearing while yellow catfish were mostly farmed in monoculture systems in Guangdong. Because we focused more on returns from yellow catfish, we may have underestimated the gross return from farms in Zhejiang relative to those in Guangdong, but the missing returns from other species is unlikely to make up the difference in gross return found on average between the 2 provinces. We could not include the returns from these other fish species because we did not have their production cost data.

Costs of producing fish in Zhejiang were lower than costs in Guangdong because farmers in Zhejiang stocked ponds in low densities. In general, farming at higher densities increases costs such as electricity and use of oxygenators, which is the first limiting factor for intensive aquaculture operations (Yu et al., 2008), and is what we found in our study. Interestingly, the cost of fingerlings and feed per production kg was lower in Guangdong than in Zhejiang and, despite the fact that feed costs are usually the highest variable costs, this difference did not offset the increased price of electricity and supplemental oxygen.

Feed is one of the most important factors influencing total cost. We found variation in farmers’ decision-making in 2 aspects of feed input influencing cost of feed to be used for the same yield of fish: source of feed (local or non-local) and type of feed (floating or pellet). In this study, price was a major factor influencing farmers’ choice of feed company. Most farmers in Guangdong chose non-local feed companies, while farmers in Zhejiang did not have an apparent preference for local or non-local sources. Expansion of the aquatic feed industry has been one of the major driving forces for aquaculture development in China. Feed price from non-local companies is usually higher. Non-local, trans-provincial companies use the branding of their products to improve their sales through large sales forces and technology service teams, which have larger organizational structures and marketing capacities than small-scale local companies. Both types of companies need middlemen to assist with sales and service. Feed payment methods might also influence feed prices. Farmers normally paid lower prices if they were able to make prepayments of 5–10% of their estimated annual feed cost, before stocking, or cash payments after shipment of feed to their farms (personal communication during interviews). According to anecdotal reports from fish health service personnel, other factors related to this decision-making process might include feedback from other farmers, and recommendations from middlemen.

We expected a low AFCR with more expensive feed. Aside from category I farms in Guangdong, it was surprising how similar the AFCRs were between farms in the 2 provinces despite the higher feed cost in Zhejiang. Category I farms in Guangdong had higher AFCR than all other farms in the study, but this might be related to use of cheaper feed. All yellow catfish farmers in Zhejiang used only floating feed, with a range of price USD 1370–1580 t, while to cut feed costs, many farmers in Guangdong used floating feed combined with powder feed, which was called Hong Kong catfish (*Clarias fuscus*) feed (about USD 483/metric ton). Farmers’ choices of feed types suggested that costs in Zhejiang could be cut and net returns could be improved. Other factors potentially affecting the net returns of farms in Zhejiang included price of fish at harvest, fingerling cost, and low fish yield per hectare.

Yellow catfish is an indigenous catfish species in China, and aquaculture of indigenous catfish species is important to local aquaculture sectors in other Asian countries, such as farming of stripped catfish (*Pangasianodon hypophthalmus*) in Thailand, Vietnam and Bangladesh. Similar to findings of this study, previous economic studies have shown that intensive aquaculture of stripped catfish is profitable in those countries (FAO, 2010; Nguyen, 2013). Relevant studies in this region indicated that return-cost ratios of stripped catfish production in Bangladesh were 1.73 ± 0.43 (mean ± standard deviation) from field studies in rural areas (Ahmed and Hasan, 2007) and 1.08–1.36 by experimental studies (Khan et al., 2009b). Because feed cost is the highest single cost component, collective evidence indicated low FCR might increase the net profit of stripped catfish aquaculture (Da et al., 2013).

Although our study identified some differences in costs and returns between similar sized farms in 2 different provinces in China, interpretation of the information collected should be done with caution as it was collected using farm surveys and not financial statements. Farm surveys are acknowledged as an indispensable tool for the estimation of costs of agriculture production (Ronzon et al., 2014). However, there are limitations to collecting financial information in this manner. It can be biased by the farmer intentionally or un-intentionally, and often prices and costs are only estimated and could be erroneous. This study had to omit several farms from the returns and costs analyses because of incomplete data, which was predominantly due to a lack of detailed record keeping of production and harvest data. As fish farms in China become larger their record-keeping improves out of necessity and, therefore, we likely biased our sampling towards more organized farmers and larger farms.

We also likely had sampling bias because we used convenience and opportunistic sampling, as there is no official list of yellow catfish farms in China from which to establish a sample frame. Further, we had limited resources for visiting farms. We received assistance from local staff affiliated with aquatic feed companies in both locations, who connected us with intermediate traders to recruit farmers to participate in the interviews. The inclusion of farmers was likely dependent on their relationships with these feed representatives. There were several farmers who had not started or completed a harvest during our interview window, so they could not provide complete information on returns and costs, and were excluded. Incomplete questionnaires were also an issue as some individuals did not want to provide economic data to us.

5. Conclusions

Our findings indicated that returns-costs ratios were slightly higher in Guangdong than in Zhejiang probably due to the higher productivity and market price. Farmers in Guangdong spent more money on fixed and variable costs, i.e. land and electricity, but feed and land rental costs were the major costs to decrease net returns in both provinces. Market price strongly affected net returns in the yellow catfish aquaculture in both provinces.

Conflict of interest

The Authors declare that there is no conflict of interest.

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