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Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus* in the Mekong Delta, Vietnam

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ARTICLE INFO

Article history:

Received 24 May 2009

Received in revised form 11 August 2009

Accepted 11 August 2009

Available online xxxx

Keywords:

Striped catfish

Farming practices

Tra

Pangasianodon hypophthalmus

Vietnam

Grow-out

ABSTRACT

Aquaculture of catfish, *Pangasianodon hypophthalmus* (Sauvage), locally known as “ca tra”, and commonly referred to as striped catfish, river catfish and sutchi catfish, in Vietnam, having recorded a production of 683,000 tonnes in 2007, valued at about 645 million US\$ is one of the largest single species based farming system, restricted to a small geographical area, in the world. The product is almost totally exported to over 100 countries as frozen fillets, as an acceptable alternative to white fish. Catfish is farmed mostly in earthen ponds, up to 4 m deep, in nine provinces in the Mekong Delta in South Vietnam. The results of the grow-out system of catfish farming in the Mekong Delta from a survey of 89 farms are presented. The farm size ranged from 0.2 to 30 ha with a mean of 4.09 ha. The frequency distribution of the yield in tonne/ha/crop and tonne/ML/crop corresponded to a normal distribution curve, where 75% of the farms yielded 300 tonnes/ha/crop or more. It was found that the yield per crop was significantly correlated ($p < 0.05$) to stocking density, pond depth and volume but not to pond surface area. Yields per crop was significantly different ($p < 0.05$) between upper and lower provinces of the Mekong Delta and water source (river versus channels), amongst others. It was evident that diseases and/or symptoms were observed to occur mostly in accordance with the onset of rains. In this paper the history of the catfish farming in the Mekong Delta is briefly traced, and current harvesting and marketing procedures as well as pertinent social elements of the farming community are dealt with.

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1. Introduction

The Mekong River (known in Vietnamese as the Cuu Long River), with a mean discharge volume of 15,000 m³/s (the 10th highest in the world), traverses 4,880 km through six countries, and divides into seven major branches when it enters the Delta, approximately 170 km from the South China Sea (van Zalinge et al., 2004). The Mekong Delta (3.92 million ha), with a catchment of 49,367 km² and a population of 17.42 million (in 2004), is popularly referred to as the food basket of Vietnam; for example, it accounted for nearly half of the national food volume (in 2000 totalling 17.5 million tonnes), 55% of the national fishery and fruit production and 61% of the national food export value (Sub-Institute of Water Resources Planning, 2003).

The culture of striped catfish, *Pangasianodon hypophthalmus* (Sauvage), also known as “ca tra” in Vietnamese, or the striped catfish and sutchi catfish, in the Mekong Delta, Vietnam, can be considered as a unique aquatic farming system in many ways. Production is the fastest

growth recorded in any aquaculture sector, ever, based on a single species, superseding the production per unit for any form of primary production (Phuong and Oanh, 2009). Furthermore, over 90% of the farmed catfish is processed and exported to more than 100 countries globally (Nguyen, 2007; Wilkinson, 2008; Globefish, 2009; Phuong and Oanh, 2009).

The striped catfish from Vietnam has essentially become an affordable ‘white fish’ substitute to the Western world, and conceivably its acceptability and popularity is growing (Intrafish, 2003; Globefish, 2009). The term ‘white fish’ is commonly used to designate fish with white flesh, common in Western countries, represented by species such as cod, *Gadus morhua*. However, in the early growth phases of the sector it had to overcome trade embargoes and related restrictions that were imposed by some importing countries (Intrafish, 2003). Currently, such restrictions on the export of striped catfish from Vietnam do not exist in most importing countries, apart from conformity to food safety and food quality standards, but many issues on its quality and the nature of farming system have been raised (Holland, 2007; Neubacher, 2007). However, most of these negative publicities have been mostly unfounded thus far (Mohan et al., 2008; Urban et al., 2008; Rehbein, 2008).

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The catfish farming sector in its present form is a relatively new development in the Mekong Delta. It is thought to have become possible when the artificial propagation of the catfish species, *Pangasius bocourti* Sauvage (basa catfish) (Cacot, 1999; Cacot et al., 2002) developed and was adopted for *P. hypophthalmus*. This development enabled the traditional small scale aquaculture practices that were dependent on wild caught seed stocks to shift to more intensified systems and depend entirely on hatchery-produced seed (Trong et al., 2002). Also, over the last decade the farming of striped catfish took precedence, and pond farming became the dominant form because of its relatively faster growth rate, flesh quality and appearance, therefore marketability overseas (Phuong and Oanh, 2009; Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009).

The present paper attempts to describe the grow-out operations of this aquaculture sector that is of immense socio-economic importance

to Vietnam, and globally as a provider of a much sought after cultured food fish commodity. The work presented is associated with a research conducted to develop “Better Management Practices” for striped catfish farming in the Mekong Delta, that is considered as a key to attaining sustainability and food safety and marketability of the commodity, as had been demonstrated previously for example small-scale shrimp farming in India (Umesh, 2007; Umesh et al., 2009).

2. Materials and methods

Catfish farming in the Delta occurs along two main branches, Tien Giang (upper) and Hau Giang (lower) and the associated channels of the Mekong River (Fig. 1). The catfish farming area falls within the jurisdiction of nine provincial administrations of which An Giang, Can Tho, Dong Thap and Vinh Long are the most important (Sub-Institute

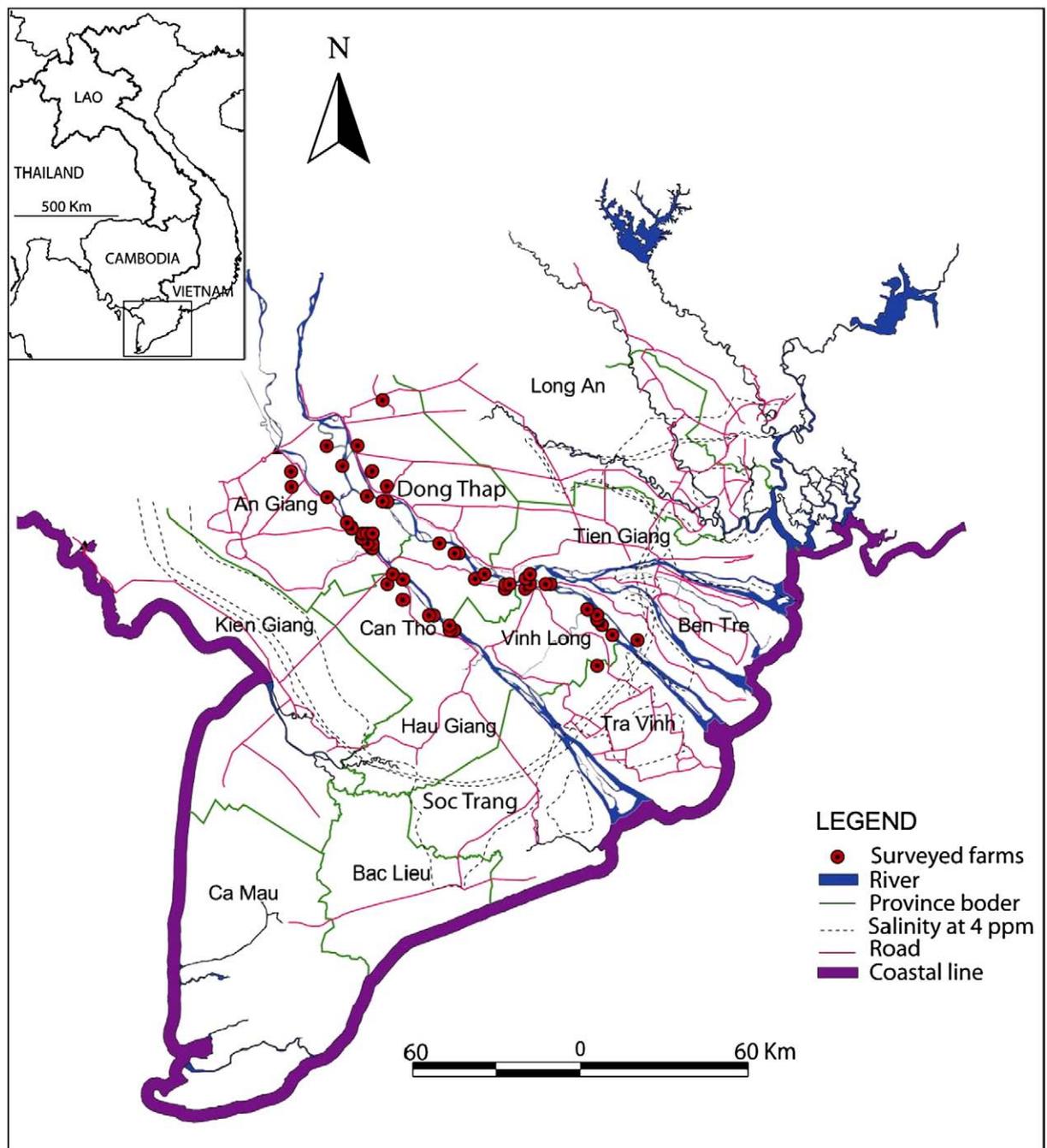


Fig. 1. The location of the main striped catfish farming areas in the Mekong Delta, Vietnam, in relation to the delta as a whole.

for Fisheries Economics and Planning in Southern Vietnam, 2009). The primary data on the farming system were collected through a structured questionnaire, farm visits and farmer interviews. A total of 89 farms (An Giang, 24; Can Tho, 15; Dong Thap, 30; and Vinh Long 20) were surveyed and the details of the area covered are given in Table 1. In each province an attempt was made to include as many districts as possible, and the farms were randomly chosen based on a list provided by the respective administrations.

The structured questionnaire for the grow-out farm survey was tested randomly and appropriately revised (available on request) for the main survey between May and July, 2008. The survey was conducted by trained socio-economists with an aquaculture background, and in each instance a minimum of three interviewers were involved on each farm visit. The responses at the interviews were primarily based on the records maintained by farmers, which in the majority of cases went back three to five years, and were very detailed.

The survey results were inputted into a customised electronic database developed using MS Access 2007 (Microsoft Corporation, USA), then exported to relevant statistical software packages such as MS Excel (Microsoft Corporation, USA), SPSS (SPSS Inc., Illinois, USA) and SAS (SAS Institute Inc., NC, USA), for performing relevant statistical analyses.

In addition relevant information on the catfish farming sector was obtained from each of the provincial and district administration offices of the Ministry of Agriculture and Rural Development (MARD), and the Provincial Governments of the Government of Vietnam. Apart from the descriptive analyses of the data, relationships between yield (t/ha/crop) and specific parameters collected during the survey were analysed using different statistical methods including simple linear regression, Pearson's product moment correlation procedure and the SAS general linear model procedure. In all instances a probability of less than 5% ($p < 0.05$) was considered as significant.

3. Results and discussion

3.1. Overall status of the sector

The trend of striped catfish production in the Mekong Delta of Vietnam has been increasing steadily over the last decade, although

Table 1
The number of operational farms in the main catfish farming provinces of the Mekong Delta in 2008.

Province/district	Grow-out	Nurseries	Hatcheries
An Giang	2891 farms (24)	1041	na
Chau Phu	813 (3)	na	na
Chau Thanh	39 (4)	na	na
Cho Moi	64 (7)	na	na
Long Xuyen	139 (6)	na	na
Phu Tan	720 (1)	na	na
Can Tho	1569 ha (15)	100	na
O Mon	(3)	na	na
Thot Not	(8)	na	na
Vinh Thanh	(4)	na	na
Dong Thap	636 farms (30)	4300	83
Cao Lanh	31 (3)	6	4
Chau Thanh	151 (8)	12	2
Hong Ngu	61 (1)	51	51
Lap Vo	48 (4)	20	1
Tan Hong	38 (1)	60	2
Thanh Binh	77 (13)	0	13
Vinh Long	346 farms (20)	94	04
Binh Tan	38 (6)	na	na
Long Ho	53 (6)	na	na
Mang Thit	782 (7)	na	na
Vung Liem	28 (1)	na	na

The number of catfish farming operations surveyed in the present study is given in parentheses (data obtained from the records of the Departments of Fisheries of the Provincial Governments; na – unavailable; note that for Can Tho the number of farms operating was not available but the acreage only).

there are discrepancies in the figures reported. Recent statistics show that the production in 2007 was the highest, when it totalled 683,000 tonnes (Fig. 2), and increased to 835,000 tonnes in the first seven months of 2008 (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009). Also, the percent contribution of striped catfish farming to total aquaculture production in Vietnam has increased significantly over the years, currently accounting for approximately 30%, becoming the most important aquaculture practice. However, the total production and the export income from the sector appeared to have been overestimated by some authors (Phuong and Oanh, 2009). The quantity of processed cultured striped catfish followed a similar trend (Fig. 3), of which over 90% is exported throughout the world that enabled Vietnam to earn approximately 645 million US\$ from this commodity in 2007 and 700 million US\$ in the first seven months of 2008 (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009), being second only to cultured shrimp and salmon in this respect of all cultured commodities globally. It is noted that VASEP (2008) reported export value in 2007 was nearly 980 million US\$. These discrepancies in production figures could have arisen in the utilisation of unconfirmed and/or preliminary estimations by some authors.

Over the last decade there had been a marked change in the major striped catfish farming systems in the Mekong Delta. In the early years, prior to 2001, when three farming systems operated; cage, pond and fence (or pen), contributing almost equally to the total striped catfish aquaculture production (Fig. 4). However, since 2003 pond culture has become predominant and currently this form dominates striped catfish farming in the Delta. The reasons for this shift are manifold and have been dealt with previously (Phuong and Oanh, 2009). The catfish farming sector supports 105,535 livelihood (full-time equivalents), and an additional 116,000 people in the processing sector the bulk of which is rural women (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009).

3.2. Farming practices

3.2.1. General information

A total of 89 farms were surveyed, most of these (97%) operated one farm site, while others operated 2–4 farm sites, and consequently some data are provided for 98 farm sites. The farm size and the water surface area ranged from 0.2 to 30 ha (mean: 4.09 ha \pm 0.48 se) and 0.12 to 20 ha (mean: 2.67 ha \pm 0.33), respectively. The number of ponds per farm and pond size ranged from 1 to 17 (mean: 4) and 0.08 to 2.2 ha (mean of mean: 0.61 \pm 0.03 se), respectively. No significant differences ($p > 0.05$) were found in any of the above parameters between provinces and between districts.

The frequency distributions of farm size, water surface area, and pond size and depth are shown in Fig. 5, and it is evidenced that farm size is highly positively skewed (skewness = 2.97), with 72% farms being less than 5 ha, and only 9% being 10 ha or greater in size. Therefore, catfish farm size in the Mekong Delta can be categorised as being primarily based on relatively small holdings, farmer owned, operated and managed, but are intensively farmed systems. This is in accordance with most aquatic farming sectors in Asia, such as in the case of shrimp farming in Thailand (Kongkeo, 1997) and in India (Umesh, 2007), and generally in aquaculture in Asian countries, such as in Thailand (Ministry of Agriculture and Cooperatives, 2006) and China (Ministry of Agriculture, 2007).

The catfish farms in Vietnam, however, are rather different from other farming sectors in Asia, in that individual pond depth ranged from 2.0 to 6.0 m with the great majority of farms (69%) with pond water depths of 3.5 to 4.5 m (Fig. 5). This practice is thought to have come about through the necessity to prevent the stock from escaping during the flood season into the main river, and therefore needing a higher dike height than in normal circumstances (Phuong and Oanh, 2009).

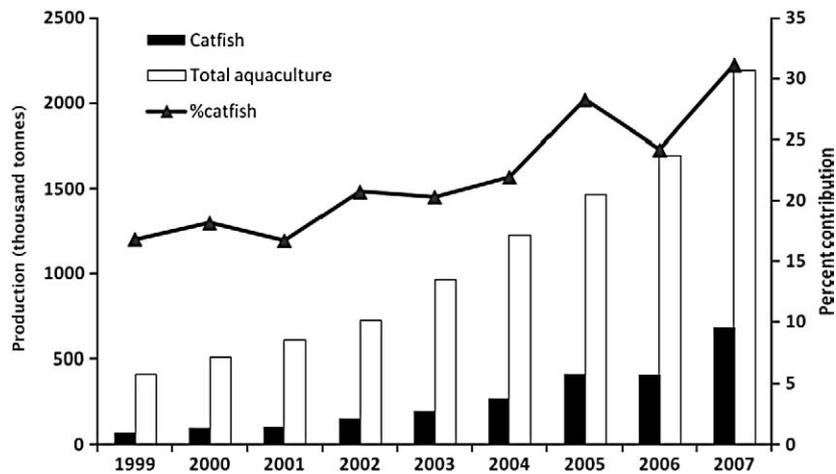


Fig. 2. The trends of change in the striped catfish farming systems in the Mekong Delta, over the last decade (based on data from Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009), together with total aquaculture production (FAO, 2007), and the percentage contribution of the former to the total.

3.2.2. Farm operations

The catfish farming operations were rarely vertically integrated, with grow-out, nursery and hatchery sectors operating as different entities, and even with some degree of specialisation of each of these activities in specific provinces/districts. For example, grow-out operations occur in nine provinces, but seed production occurs mainly in An Giang and Dong Thap provinces, where there is a concentration of hatcheries and nurseries (see Table 1).

3.2.2.1. Water supply and pond preparation. Of the 98 farm sites surveyed, 80% obtained water directly from the main river and the rest from rivulets and canals. Only 6% of farms screened the inflowing water and similarly only 3% of the farms used sedimentation ponds prior to supplying water into the rearing ponds. Majority of the farmers were of the view that screening was not essential and as for sedimentation ponds the cost of land makes this option prohibitive to most.

All farms surveyed treated pond bottoms prior to filling up with water and stocking. The fallow period was highly variable, and ranged from 2 to 45 days with 16, 16, 24 and 11% of the farms following a fallow period of 7, 10, 15, and 30 days, respectively. During the fallow period, the type of treatments adopted differed between farms. The preferred methods of pond bottom treatment included liming (96% of farms), sludge removal (82% of farms) and salt treatment (71% of farms). In addition, 57% of farms applied chlorine before draining the ponds and refilling.

When the ponds are filled, farmers adopted a varying number of treatments prior to stocking. The most preferred treatments were

application of chlorine (29% of farms), lime (27% of farms), benzalkonium chloride (BKC) (15% of farms) and salt (11% of farms). The amounts applied were also variable and did not follow a prescribed pattern or any guidelines.

3.2.2.2. Stocking. In general, an apparent difference on seed production and nursery rearing was evident amongst the provinces. For example, the major seed producing provinces were An Giang and Dong Thap (Table 1). Hatchery production of catfish occurs throughout the year with peaks from February to September, but the data did not suggest any relationship of seed production intensity to rain fall pattern and/or any other climatic factor. The seedlings are reared in specialized nursery facilities to a size of 1.0 to 8.5 cm (mean 4.5 cm) as fry or 1.2 to 20 cm (mean 8.6 cm) as fingerlings, when these are purchased by grow-out farmers for stocking. The furthest distance that stocking material would be obtained is about 100 km. The stocking size ranged from 1.5 to 18 cm (mean 7.8 ± 0.97 se) and ponds are usually fully stocked at the one time.

Stocking densities, which varied from 18 to 125 fish/m² (mean 48 ± 2.1 se) and 5 to 31 fish/m³ (mean 12 ± 0.5 se), depended on the size and availability of seedstock and the financial capacity of farmers to purchase seedstock. Most farms (74%) stocked ponds on multiple occasions (staggered stocking) within a short time frame, however. Over 90% of farms tested the seed in terms of uniformity in size, diseases and general activity before stocking. Most farms (76%) treat the seed before stocking, and the majority of farms used salt (78%) and antibiotics (32%) for this purpose.

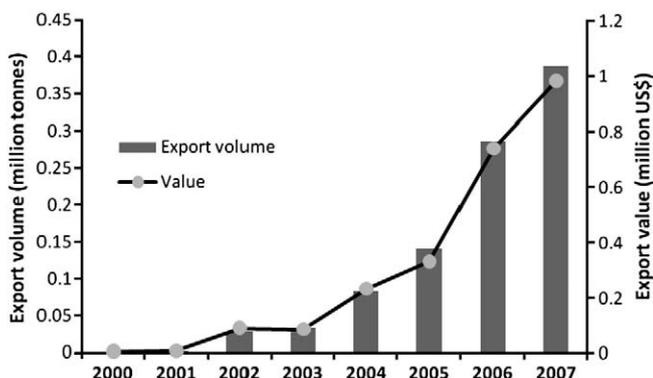


Fig. 3. Trends of in the export of frozen fillet tonnage and corresponding value (in US\$). Based on data from VASEP (2008).

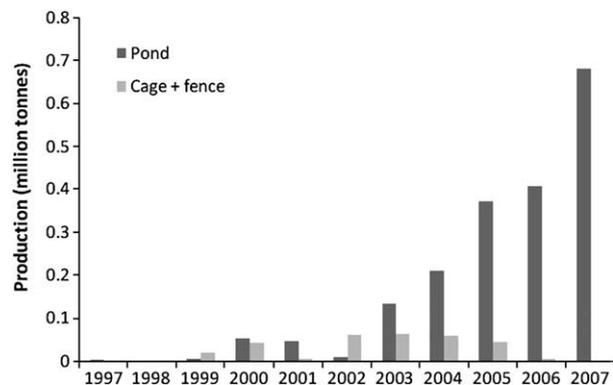


Fig. 4. Trends in the common farming systems of catfish in the Mekong Delta, based on data from the Sub-Institute for Fisheries Economics and Planning in Southern Vietnam (2009).

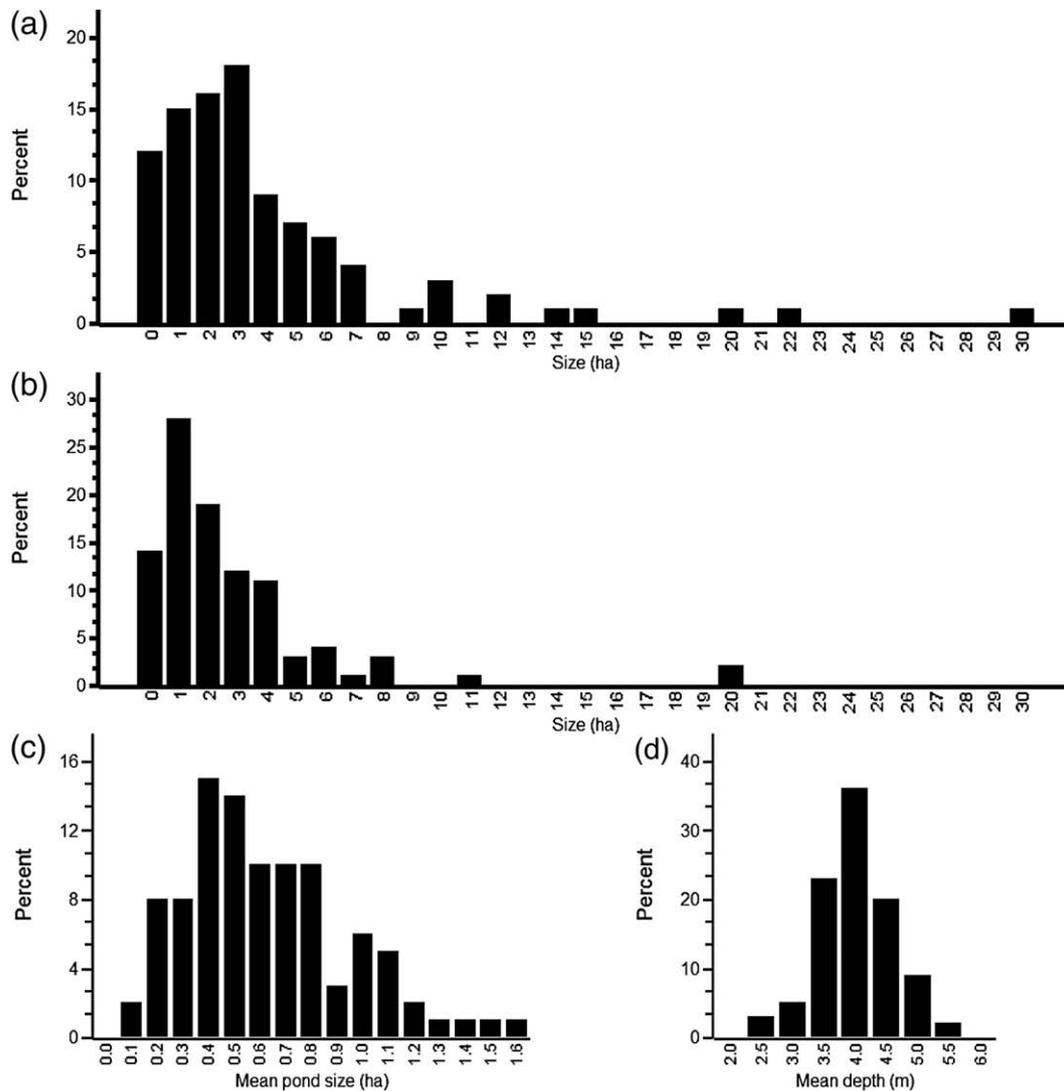


Fig. 5. Frequency distribution of (a) farm size, (b) farm water surface area, (c) mean pond size, and (d) mean pond depth, of the farms surveyed.

3.2.2.3. Feeds and feed management. Most farms (97%) use commercially made feed, which is purchased directly from the feed mills or from local merchants, while, 37% of farms used farm-made feeds, 49% of which was produced on site. It was observed that 67, 80.0 and 17% of farms surveyed in An Giang, Can Tho and Dong Thap used farm-made feeds, respectively, yet none in Vinh Long. It should be noted that all farm-made feeds were not necessarily made on site, some opted to purchase from neighbours. A similar trend has also been reported for the intensive Indian major carp farming systems in Andhra Pradesh, India (De Silva and Hasan, 2007). Given the large fish feed market in the Mekong Delta, many international and national feed millers have attempted to establish in the region to obtain a share of this market; 37 companies supplied feed to surveyed farmers.

The quality of the commercial feeds available is highly variable with protein content ranging from 20 to 30% (mean 25.8%) (Table 2), whilst that of farm-made feeds ranged from 17 to 26% (mean 21.6%) (authors' observations). Detailed studies conducted on the quality of commercial and farm-made feeds have shown that, contrary to the popular belief, the moisture content of the two types of feeds is not significantly different ($p > 0.05$), varying from 8 to 10% (De Silva, unpublished data). The main ingredients used in farm-made feeds were trash fish (marine origin), fishmeal and in most cases powdered and or crushed dried fish (mostly of freshwater/brackish water origin from the flood plain areas in the Delta; see De Silva, 2008 for details), soybean meal, broken rice and

rice bran (Table 3). Vitamins, probiotics, pre-biotics and premixes were also included in farm-made feed.

Feeding rates ranged from 1 to 18% and 1 to 10% body weight/day for commercial feeds and farm-made feeds, respectively, were highest at the beginning of the production cycle when fish were small (Table 4). Feeding rates for farm-made feeds were generally greater than for commercial

Table 2

The proximate composition of a random selection of commercial feeds, as specified on the bags, used in catfish grow-out operations in the Mekong Delta.

Feed no.	Maximum moisture (%)	Minimum protein (%)	Minimum total lipid (%)	Maximum ash (%)	Maximum fiber (%)
01	11	30	5	na	6
02	11	22	4	10	7
03	11	26	5	10	7
04	11	28	5	10	6
05	11	22	4	10	8
06	11	26	5	10	7
07	11	26	3	14	7
08	11	28	3	14	6
09	11	26	3	12	7
10	10	26	5	na	8
11	11	20	4	na	8
12	11	30	5	na	6

The names of the producers are withheld for ethical reasons (na – not available).

feeds throughout the production cycle. Fish were typically fed twice per day, but some farms fed up to six times per day (Table 3). The food conversion ratio (FCR = amount of feed used ÷ increase in biomass) for commercial pellets and farm-made feed ranged from 1.0 to 3.0 (mean 1.69), and 1.3 to 3.0 (mean 2.25), respectively, which differed significantly ($p < 0.001$) from each other. The relationship between diet type and yield was insignificant ($p > 0.05$), but production cycle if using farm-made feed is usually 4–8 weeks longer.

Based on a mean FCR of 1.69 for commercial feed with a protein content of 25%, and assuming that 30% of the nitrogen in the feed is converted into fish flesh (De Silva and Anderson, 1995), it is estimated (gross) that 47.3 kg nitrogen is discharged per tonne of catfish produced. On this basis, in 2007, when 683,000 tonnes of catfish was produced in the whole of the Mekong Delta, approximately 32,306 tonnes of nitrogen was discharged into the Mekong River. If the production was to reach 1 or 1.5 million tonnes of catfish in the ensuing years the corresponding nitrogen discharge would approximate 47,300 and 70,950 tonnes per year, respectively.

However, one could expect the increase in production to go hand in hand with improvements in feed quality and management, and these are likely to result in significant lowering of the nitrogen discharges from the above levels. When compared to inputs from other agricultural activities in the Delta, the amount of nitrogen discharged into the main river from catfish farming is almost negligible. For example, it has been estimated 170 to 182 kg of plant nutrients were applied per sown ha of paddy (in 2000 paddy farming in the Delta was 7.48 million ha) (Truong, 2003). A detailed comparative study on the nutrient loadings from different primary production sectors in the Mekong Delta is warranted, and will facilitate a more holistic ecosystem management approach to be adopted.

3.2.2.4. Water management. As expected in this very intensive form of catfish farming, water management plays a crucial role. Nearly 77% of farmers monitored the water quality in fish ponds, with varying frequency ranging from daily to once a month. The common parameters monitored were pH, DO and ammonia and the monitoring was done using commercially available test kits and probes.

During the first two months following stocking, water was exchanged at infrequent intervals ranging from daily to once a week. However, in latter months the frequency of exchange was gradually increased up to twice a day, especially close to harvesting time. The rate of exchange at any one time ranged from 30 to 100% replenishment. Some farms relied on daily tidal flushing of ponds.

Table 3
Main ingredients used in farm-made feeds.

Ingredient	Percent dry weight	g/kg feed (when used)	Frequency of use
Broken rice	0–66 (13.4)		
Rice bran	0–80 (39.4)		
Fishmeal	0–50 (9.3)		
Trashfish	0–50 (14.8)		
Soybean cake	0–20 (1.7)		
Soybean meal	0–30 (9.9)		
Other ^a	0–55 (12.9)		
Methionine		0.05–2 (1.1)	Daily to once per week
Mineral		0.5–1 (0.8)	Variable
Premix		0.02–40 (3.4)	Daily to twice per month
Pre-biotic (glucan)		0.01–25 (3.4)	Daily to once per month
Pro-biotic		0.2–40 (2.6)	Daily to twice per month
Sorbitol		0.05–3 (1.3)	Variable
Vitamin C		0.05–20 (2.3)	Daily to only when fish are sick
Other additives ^b		1–70 (8)	Daily to once per month

The range in percent dry weight of the ingredients used in farm-made feeds together with other additives (where relevant the mean is given in parentheses).

^a Egg, cassava, catfish extract oil, marine trapfish.

^b Lysine, Vitalex, Vemedin, Vimidine, Prozyme, Pangarenol.

Table 4
Ranges in feeding rates (%/body weight/day) and frequency (mean in parentheses) in catfish farms using commercial and farm-made feeds in the Mekong Delta.

	Early: months 1–2	Middle: months 3–5	Late: months 6–7
Fish size (g)	17–150 (78)	45–1000 (337)	500–5000 (968)
Commercial feed	1–18 (5.6)	1–7 (3.2)	1–5 (2.0)
Farm-made feed	3–10 (5.7)	2–5 (3.9)	1–3 (2.3)
Feeds per day	1–4 (2.2)	1–3 (2)	1–6 (1.8)

Farms mainly discharged water directly into the main river (63%), primary canals (19%) or onto rice fields or gardens (11%). Only 7.8% of farms screened the water before discharging while 11.2% of farms treated the discharge water, commonly with chlorine or lime. There was no apparent understanding between adjacent farms with regard to intake and discharge of water.

Aspects of water management impacts on fish production are dealt with in Section 3.2.3.

3.2.3. Production

Catfish farm yields ranged from 70.0 to 850 tonne/ha/crop (mean 406 ± 16 se) or, accounting for mean pond depth per farm, 1.5 to 22.7 tonne/ML/crop (mean 10.4 ± 0.4 se). The frequency distribution of the yield in tonne/ha/crop (Fig. 6) corresponded to a normal distribution curve, where 76% of the farms yielded 300 tonne/ha/crop or more. However, the yields at the two extremes are not the norm. Very low yields occur in few farms due to unforeseen mortalities, generally early in the growth cycle. Conversely, yields above 550 tonne/ha/crop are seen in farms which tend to retain the stocks until acceptable market prices are realised. This option also involves an increase in the culture period. The findings from the present study is consistent with those of the Sub-Institute for Fisheries Economics and Planning in Southern Vietnam (2009), which reports the yield of 200–400 tonne/ha/crop.

Water consumption per tonne of fish produced, which was estimated from fish production, farm water volume and water exchange rates for each farm, was highly skewed and ranged from 0.7–59.7 ML/tonne (mean 6.4 ± 0.8 se) (Fig. 6) (0.017–1.412, mean 0.292 tonne/ML). In comparison, water consumption in shrimp farming in ponds ranges from 11 to 43 ML/

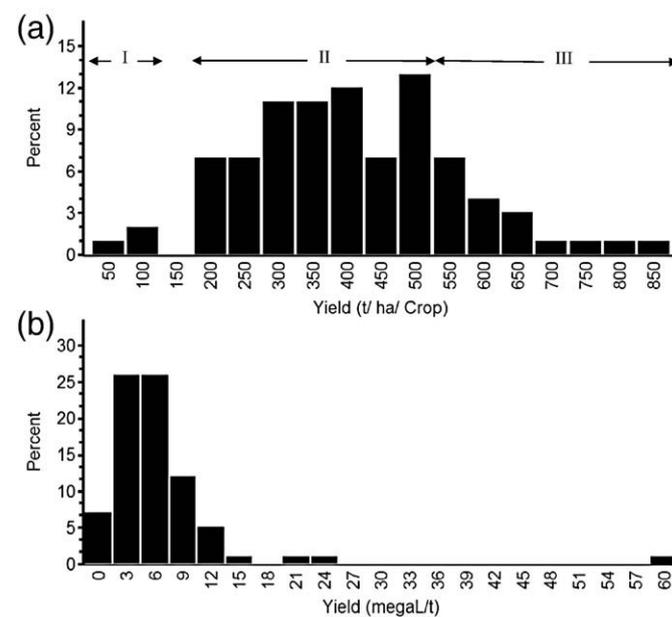


Fig. 6. Frequency distribution of production in tonne/ha/crop (a) and tonne/ML (b) of striped catfish farms surveyed in the Mekong Delta. The three ranges in yields I, II, III indicate low yield arising from mortality (I), normal cycle yield (II) and unusually high yields arising from farmers retaining stock until acceptable prices are realised (III).

tonne, tank culture of salmonids – 252 ML/tonne (Beveridge et al., 1991). Overall, based on the data in 2007, when 683,000 tonnes of catfish was produced in the whole of the Mekong Delta, 4371 GL of water was used, of which 2754 GL was discharged back to the river. As such the amount of water used for the production of a tonne of catfish was 4,023 m³, approximately 10% higher than the estimates of Bosma et al. (2009).

The yield was positively and linearly correlated to stocking density (fish/m² and fish/m³), pond depth and pond volume, and the relationships are depicted Fig. 7. However, yield was not correlated ($p > 0.05$) to pond and farm surface area and/or to fish size at stocking (length and weight). The Sub-Institute for Fisheries Economics and Planning in Southern Vietnam (2009) however, found a significant relationship between total culture area and total production ($Y = e^{0.01x + 915.131}$; $R = 0.96$, $p < 0.05$, $F = 118.9$) and predicted that catfish production would reach over 1 million tonne/year with a total culture area of about 6,000 ha.

The data were analysed to explore relationship of the yield to a number of other parameters, such as location (provinces), the distance from river mouth, source of water (directly from the river versus canals), water exchange rate calculated as the volume exchanged per week and frequency of water exchange per week, age of the farm and feed type used, and the results are shown in Fig. 8. Interestingly, the mean yield for each province did not differ significantly from each other (Fig. 8a) but when the provinces are separated into upper and lower catchments it was significantly ($p < 0.05$) different (Fig. 8b), where the yields in farms in the upper catchment were higher. It is difficult to discern the reasons for this trend and perhaps need further studies on details of the catchment characteristics. However, it is possible that the greater tidal range impacts in the lower region, with potential higher salinity fluctuations influencing growth of the stock, and hence resulting in an overall reduction in mean production.

In addition to the above, the mean yield of catfish in farms that drew water directly from the river was significantly higher than those

farms that drew water from canals (Fig. 8c). This may have contributed to the regional difference in production since 83% of farms in the upper catchment drew water from the river compared to 78% of farms in the lower catchment. Surprisingly, however, yields were not correlated to water exchange frequency and/or the volume exchanged per week, and the means for each of these parameters also were not significantly different ($p > 0.05$) from each other (Fig. 8d) and nor was the yield to the distance from the sea mouth.

The feeds used in catfish farming are variable, as pointed out previously in Section 3.2.2.3. Interestingly, the mean yield of farms feeding farm-made feeds was higher compared to the other two, though not significant (Fig. 8f). However, culture cycle when using farm-made feed is often 4–6 weeks longer than using commercial feed. The efficacy of use of farm-made feeds as opposed to commercial feed has been a bone of contention, on the ground of resource usage, environmental impacts, amongst others, for many aquaculture commodities (New et al., 1994; Hasan et al., 2008). However, it has also been shown previously in respect of shrimp farming that farm-made feeds resulted in higher efficacy than commercial feeds (Wood et al., 1992). In the catfish farming sector, majority of farmers was of the view that using farm-made feed not only resulted in a better production but also was cheaper or more cost effective. For example, from the survey results the unit production cost for farm-made feed was $13,722 \pm 1385$ VND (range: 11,500–15,500) as opposed to $14,372 \pm 1374$ VND (range: 11,000–17,000) for commercial feeds. However, this difference was not statistically significant ($p > 0.05$). Farmers generally had difficulty in sourcing the required ingredients on a regular basis and as a result resorted to using commercial feeds.

3.2.4. Disease occurrence

Levels of cumulative mortality varied from one farm to the next as well as throughout the production cycle. Mortality of fish in the first week following stocking ranged from 0–30% (mean 7%). The level of

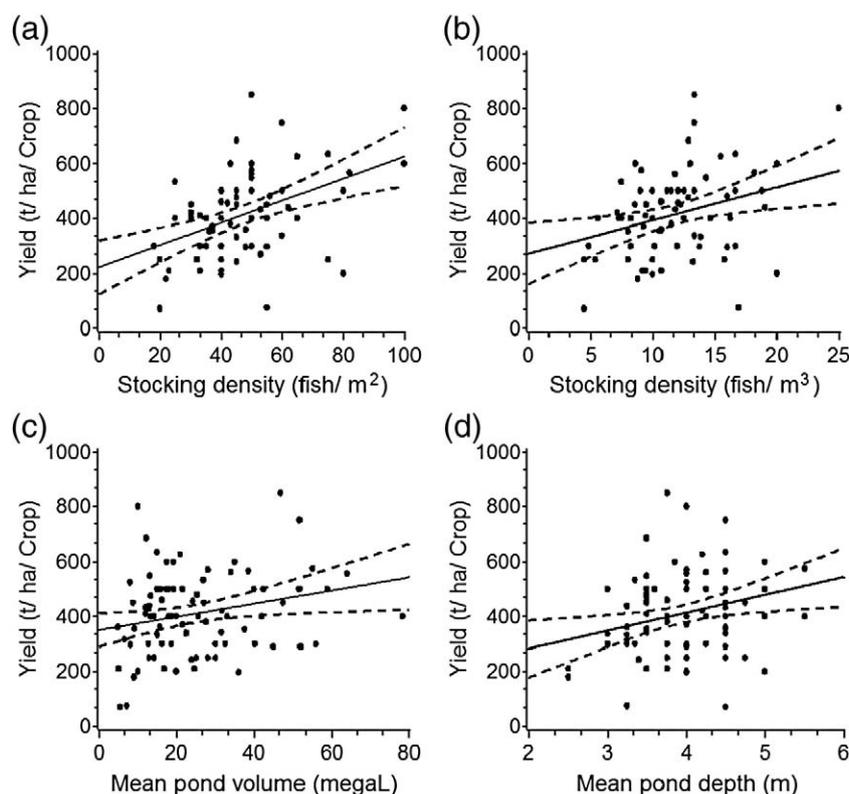


Fig. 7. Relationships between yield (tonne/ha/crop) and (a) stocking density as fish m⁻² (yield = $221.2 + 4.03 \times \text{density}$ (adj. $R^2 = 0.1742$, $p = 0.0001$), (b) stocking density as fish/m³ (yield = $270.5 + 12.0 \times \text{density}$, adj. $R^2 = 0.08$, $p = 0.008$), (c) pond volume (yield = $348.5 + 2.4 \times \text{volume}$, adj. $R^2 = 0.0470$, $p = 0.0235$), and (d) pond depth (yield = $149.4 + 65.3 \times \text{depth}$, adj. $R^2 = 0.0615$, $p = 0.0117$). Broken lines represent 95% confidence limits for mean predicted values.

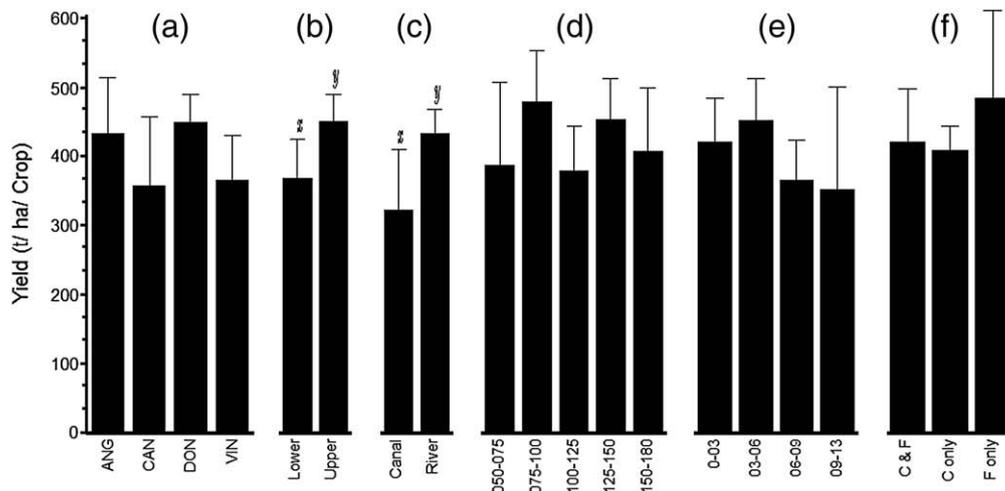


Fig. 8. Farm yield (tonne/ha/crop) for (a) different provinces, (b) different regions (lower = Can Tho and Vinh Long, upper = An Giang and Don Thap), (c) water source (river or canal), (d) distance from Delta mouth (km), (e) age of farm (years), and (f) Feed type (C and F = both commercial and farm-made feed used. C only = commercial feed used only. F only = farm-made feed used only). Italicised notations above bars indicate significant differences ($p < 0.05$).

mortality was typically up to 30% during the early to mid months of the production cycle and <10% in later months. Three farms only reported a level of mortality >30%. Diseases and poor weather conditions were the most common reasons given by farmers for mortality events.

Farmers reported 15 different symptoms and/or diseases, with bacillary necrosis of *Pangasius* spp (BNP) (Edwardsiellosis) (98% of farms), parasites (88%), redspot in flesh (61%), spot disease (58%), white gills (30%) and slimy disease (28%) being the more common diseases, and BNP, parasites and white gills being the more severe diseases. BNP is recognised as an economically significant pathogen of catfish in the Mekong Delta (Crumlish et al., 2002; Dung et al., 2004), which can cause 50–90% mortality (Dung et al., 2004). The occurrence of symptoms/diseases was highest in June and July which corresponded with the onset of the wet season and increased rainfall (Fig. 9). Clearly, this is an area that warrants more systematic pathological and epidemiological investigations.

Management of health on catfish farms mainly involves chemical treatment, often with antibiotics, use feed additives (vitamin C) and regular water exchange. Farmers mainly bury or sell dead fish and disturbingly, 30% of farms sell dead fish to other fish farmers which represents a significant pathway for disease transfer.

3.2.5. Harvesting and marketing

Fish were harvested at the size of 0.6 to 1.5 kg (mean 1.0 kg), after a growth period of about 6–7 months. The produce was sold directly

to processors after negotiating for price and subjected to quality tests, particularly for banned chemicals. Processors tested samples of fish in terms of appearance, flesh colour and chemical residues prior to purchasing. It was rather unusual that no middlemen were involved in the marketing process, as often seen for many market chains for aquaculture produce in the region (De Silva, 2008).

Grow-out farmers often had a prior contract with processors and it was observed that 89% of the farms surveyed accepted prior payment from the buyers, ranging from 10–50% of the total estimated selling price. Sometimes farmers (41%) also accepted delayed payments from the buyers, especially when there was limited demand from the processing plants.

Harvesting a pond was done using seine nets after draining 60–80% of the water, and was generally completed within four days (up to 12 days). It was often the buyers that provided transportation of harvested produce to the processing plants, either by river in the hull of boats that specialized in transportation of live fish or by road in trucks equipped with live fish holding tanks.

3.2.6. Farming communities

The farming communities are relatively young, with the age of owners and technical managers ranging from 23–65 years old, but the majority (>96%) being under 50 years old. The education levels attained by owners and technical managers up to primary school, secondary school, high school, college and university were 10, 23, 27,

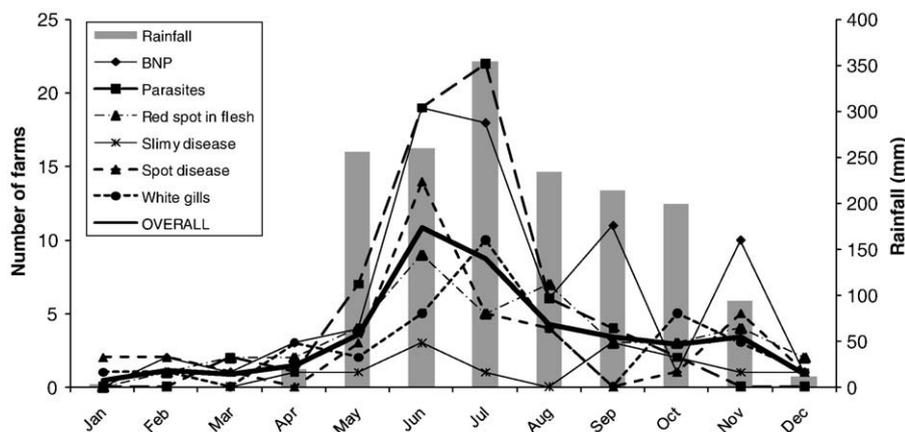


Fig. 9. Common diseases found in catfish in the production cycle. Rainfall (mm) are average values obtained from nine provinces of the Mekong Delta.

6, 20% and 6, 24, 17, 7 and 19%, respectively. It is interesting that only one owner and nine technical managers had an aquaculture degree. The majority of farms gained catfish farming experience through family tradition (39%), training (40%) and other farmers (40%), but there were marked differences among farmers in the different provinces. For example, the number of farmers in An Giang that learnt from family tradition was about 50%, while farmers in Dong Thap gained experiences from family tradition, training and other farmers, and farmers in Vinh Long mainly gained their skill through official training and other farmers.

Labour ranges from 1–100 (mean 11) people per farm, with 0–100% (mean 19%) of labour being made up of family members. Female workers made up 0–50% (mean 10%) of the farm labour force and were involved in almost all activities such as management, labour, feeding, harvest, and making decision with regard to buying and selling.

Sixty seven percent of farmers indicated that the standard of living had increased since taking up catfish farming, but only 11% of farmers plan to expand the farm in the future. The most commonly cited reason for this is because of unstable or low fish price. Farmers considered cost of production, low or unstable markets and disease issues were the main problems facing the industry. Information available from the Department of Agriculture An Giang province indicates that the catfish farming in the province has decreased by 19.7% (274 ha) between April 2008 and May 2009.

3.2.7. Economic viability

The fixed investment of a catfish farm is relatively large and deviated highly from farm to farm. Overall, fixed costs ranged from 7 million to 15.23 billion VND (1 US\$~15,900 VND at the time of survey) with main costs being attributed to pond construction (mean 32%) and land purchase (mean 30%) followed by storage (mean 12%) and facilities (mean 10%). Fifty four percent of farms were built on land owned by the farmer. Operating costs ranged from 84 million to 46.5 billion VND per farm per crop with a large proportion attributed to feed costs (mean 75%) and seed costs (mean 12%). Production cost per kg of fish ranged from 11,000 to 17,000 VND (mean 14,200 ± 150 se).

4. General conclusions

The catfish farming sector in the Mekong Delta is unique in many aspects. It is the largest farming sector based on a single species in one geographical area. The farming system has reached the current status within a decade or less surpassing any form of aquaculture development in the world. In view of the fact that almost all produce are exported the sector has supported a large processing sector where 90% of the employees are women. It is predicted that labour requirement of catfish farming sector is up to 42,000 people in 2015, and require 210,000 people working in the processing sector (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009).

It is important to note that the development of the catfish farming sector in the Mekong Delta, within a relatively small geographical area, has enabled a number of subsidiary service sectors to develop and service effectively. Foremost amongst these are the feed manufacturers and the associated transportations, the processing sector and the associated re-processing of waste, fresh fish transportation sector (by boat) to processing plants, packaging and freezing and road transportation of products for export. It has been estimated that these sectors provide about 10% of the total livelihood opportunities to those in the Delta.

Being a relatively new and a fast developing sector, it has impacted on the socio-economic *milieu* of the region to a great extent but a quantitative assessment of these aspects are still to be made. One of the most significant impacts in this regard has been on the land prices. All in all the catfish farming sector is in conformity with other aquaculture practices in Asia in that most farms are small scale, farmer

owned, managed and operated. However, it is evident from the study that some bigger farms are emerging and these are primarily associated with big processors who are striving to establish vertically integrated systems, with a view to becoming as independent as possible on small producers for the raw material for processing.

The catfish farming sector has had to deal with many marketing problems particularly in respect of export to the US. These aspects have been dealt in detail previously (Intrafish, 2003; Kinnucan, 2003; Sengupta, 2003; Quagraine, 2006). The findings of these studies tend to indicate that the imposition of trade embargoes and labelling laws introduced by the US had an indirect but a positive influence on the catfish farming sector resulting in the development of an expanded international market and an increase in the unit price.

The catfish farming sector in the Mekong Delta has in all probabilities achieved its greatest height. Expansion of the sector in space is likely to be small or none because of the escalating and almost prohibitive land prices along the river front, and the growing competition with other developing sectors such as tourism, and up-market real estate development (Bosma et al., 2005). Nevertheless Vietnam targets to produce between 1.3 to 1.5 million tonnes of catfish worth of an export value of 1.5 billion US\$ in 2009 (Globefish, 2009).

The sector can and should be able to improve on production through the adoption of better management practices (BMPs) as has been done in the case of shrimp farming in Andhra Pradesh, India (Umesh, 2007; Umesh et al., 2009). A number of immediate management measures are likely to be useful at striving to achieve BMPs. Foremost amongst these would be a planned, well-managed system of water intake and discharge introduced for clusters of farms within a geographic location. Equally, as the study shows the commercial feeds do not perform significantly any better than farm-made feeds, suggesting that improvement in feed quality are urgently warranted.

In general, most intensive aquaculture system are more often than not, targeted by environmental lobby groups. It has been shown in this study that the total estimated annual discharge of nitrogen into the Mekong River with an annual discharge of 15,000 m³/s, the tenth highest in the world (van Zalinge et al., 2004) is less than 33,000 tonnes (in 2007 for example). This tantamounts to a very small fraction of the total potential discharge from other agricultural activities as well as from human waste with a population of 17.2 million in the Delta. On the other hand, it has been suggested that the water quality in the Mekong River between 2005 and 2008 was hardly modified compared to the period prior to the expansion of the catfish farming sector (Bosma et al., 2009). This however, is not a matter for complacency, nor does it preclude the fact that further improvements in the manner that effluent is discharged are needed, perhaps best done through the introduction of sedimentation ponds prior to discharge.

Mekong Delta is considered likely to be significantly impacted within the next decade or so by climate change, principally through sea level rise and corresponding sea water intrusion and reduced river flow rate (White et al., 1996; Ho, 2008). De Silva and Soto (2009) have pointed out that if the current catfish farming in the Delta is to be sustained there is a need for suitable adaptive measures, foremost of these being the development of salinity tolerant strains of striped catfish, and the associated changes in hatchery production be put in place sooner rather than later.

Acknowledgements

This work was undertaken as a component of the Collaboration for Agriculture Research and Development (CARD) program between the Governments of Vietnam and Australia, funded through the Australian Agency for International Development (AusAID). The current project is a component of the project "Development of better management practices for catfish farming in the Mekong Delta" (VIE 001/07). We are grateful to the financial support provided by AusAID. Most of all, our thanks are due to numerous farmers who were very

willingly forthcoming with information and provided access to their records unreservedly. We value their friendship and cooperation.

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