Supply and use of catfish (*Pangasianodon hypophthalmus*) seed in the Mekong Delta of Vietnam

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Aquaculture in inland water bodies in the Mekong Delta has developed rapidly since the 1990s, and is the most important contributor to Vietnam's fishery sector in terms of both domestic consumption and exports. Pangasius catfish, including *Pangasianodon hypopthalmus* (ca tra in Vietnamese) and *Pangasius bocourti* (ca basa) were traditionally cultured in the region from 1960s using wild caught seed harvested from the Mekong River. Farming of tra fish in particular has become highly developed since the closing of the lifecycle in 1996 and the development of a commercial hatchery sector from 1998 onwards. Good bio-physical conditions, improved farming techniques and growth of international markets are the main reasons for the broad spread of tra farming in freshwater areas of the delta, and this species now contributes more than 98% of the total production of Pangasiid catfish in Vietnam.

For years, An Giang and Dong Thap provinces, located close to Cambodia where much wild seed was harvested, were the major sites for production of tra in the delta, but a shift from cage-based to pond-based culture has provided opportunities for the expansion of production into other provinces lying along the main Hau and Tien branches of the Mekong. In the 10 years from 1998 to 2007, the total area under culture increased six times, to about 6,000 ha. Annual commercial production of tra increased 45 times over this period, from 22,500 tonnes to more than 1,000,000 tonnes. The volume of exported tra fillets jumped more than 55 times over this period from 7,000 tonnes to 386,870 tones, and export values increased 50 times, from US$ 19.7 million to US$ 979,036 million. Tra is now exported to more than 80 countries and territories, in all continents. By 2008, nine of the thirteen provinces and cities of the Delta produced tra for export. Total production of tra in 2008 was estimated about 1.2 million tonnes, and the total production of exported fillets was 650,000 tonnes, with a total export value of approximately US$1.45 billion (Dung, 2008). Sinh (2007) also estimated that a total of about 0.2 million people in the Mekong Delta are associated with the tra fish industry.

Further development of the tra culture in the Mekong Delta is limited by a number of interrelated factors, however. Lack of appropriate planning is said to be a macro problem for development of the Pangasius industry. Seed accounts for about 10-20% of the total production costs and many catfish farmers reported that the stocking time or the time to stock fingerlings, quality, and quantity of purchased fingerlings as important concerns. Feed usually accounts for more

Pond culture of tra catfish.

than 75% of the operating costs for tra production and can negatively impact water quality, resulting in increased incidence of disease in stocked fish. The increasing prevalence of environmental issues and marketing problems related to the quality of products and high levels of competition are also serious considerations for the entire Pangasius industry, in the Mekong Delta of Vietnam and in neighbouring Cambodia (Dung, 2005; Sinh & Nga, 2004; Sinh et al., 2006; Phuong et al., 2007; Son, 2007; Dung, 2008; Loc et al., 2008; Phan et al., 2009). This study therefore aims to describe and to analyze the supply and use of tra seed (both fry and fingerlings) in order to provide a set of recommendations for further development of this species in the Mekong River Delta.

This study was carried out from June 2007 to December 2008. The investigation covered nine provinces of the delta where producers engage in export-led tra production. These provinces were categorized into two groups. Group 1 included five inland provinces (An Giang, Dong Thap, Can Tho, Vinh Long and Hau Giang), and group 2 consisted of four coastal provinces (Tien Giang, Ben Tre, Tra Vinh and Soc Trang). The total sample size comprised 33 hatcheries; 39 nursery sites; and 293 grow-out farms. A structured survey based approach was used to generate quantitative data which would provide an indication both of major issues affecting the industry relating to seed, and allow for analysis of the links between differing management practices and the profitability of operations.

The results show that the age of experience in the Pangasius industry were 7.6 years, 10.6 years, and 3-5 years for hatchery owners, nursery site managers and grow-out farmers, respectively. Fish farmers in inland areas had longer experience than those in the coastal provinces (5 years compared with 3 years). The owners/farmers combined the knowledge from experience and training courses (56.3% of the number of hatcheries; 31.6% for nursery, and 39.2% for grow-out) or only rely on their own experience (hatcheries: 40.6%, nursery: 50%, and grow-out: 48.8%).

Hatcheries and nursery sites (supply side)

Tra hatcheries

At the end of 2007 and the beginning of 2008, there were 93 hatcheries of tra fish in the Mekong Delta, mostly located in Dong Thap and An Giang provinces. These hatcheries had an average total area of 8,303 m^2, of which maturation ponds comprised 864 m^2 (±643 m^2) with an average water depth of 2.2 m (±0.4). The average design capacity of hatcheries was 818.3 million hatchlings/year, and ranged from 50 to 1,500 million hatchlings, but most had a capacity smaller than 500 million hatchlings/year. On average hatcheries had 290.4 m^3 of weis tanks (incubation jars for hatching fertilized spawn), with a range from 50 to 1,152 m^3.

Low fecundity during the cold season (lunar November to January) meant that most hatcheries operated from lunar February to October. February to June was reported by 65.2% of hatcheries to be the best time for reproduction. On average hatcheries were run for 29.8 production cycles/year, with a duration of about 7 days per cycle from the hatching of eggs to the sale of fry. This is an increase in the number of cycles/year compared with the 17-19 reported by Yen (2006). This might suggest a growing potential for negative impacts on the yield and quality of hatchlings if broodstock replacement is not adequate.

Broodstock were sourced from other farms (78.1% of the number of hatcheries) or from the wild (6.3%). The remaining hatcheries (15.6%) used broodstock from both sources. The amount of broodstock conditioned for spawning depended on hatchery size. The average size of male and female fish was found to be approximately 4.0 kg/fish (±0.9), with an average ratio of females to males of 3.45 (±1.28). This is considerably lower than the 1:1 ratio recommended by Tave (1993). A quarter of hatcheries reported that the quality of broodstock was not good enough in terms of fecundity and egg quality. The average age at breeding females was 4.6 years (±1.1). Each breeder was used about 4.2 times/year (±1.4, ranging from 2 to 8 times). Average fecundity was 150g of eggs per kg of female (a GSI of 15%). Eggs were stocked in incubation jars at a density of 179,000 eggs/litre; a range of 86,000 to 300,000 eggs per jar. The hatching rate was from 70% to 95% and averaged 83.8±6.8. Hatchery operators considered the hatching rate of eggs, and good movement, good color, and uniform size of hatchlings to be the main indicators of good seed quality.

The total annual production of tra fry produced in the Mekong Delta in 2007-2008 was estimated at 52 billion. Average yield per litre of weis tanks was 2.85 million fry/litre/year (±3.39). Using the exchange rate in 2007-2008 (USD 1 = VND 16,500), each hatchery spent an average of VND 588.3 million (±564.0) or USD 30,655 per annum, of which 96.7% was for variable costs. Among the annual production costs or variable costs, the three most important items consisted of: 1) feed (44.0%); 2) chemicals and drugs (24.2%); and 3) new broodstock (10.3%). On average hatchery owners gained a total net income of VND 802.2 million/hatchery/year or USD 48,618 but this figure obscures a great deal of variation (± VND 798.2) much of which is related to differences in hatchery size. It is noteworthy that all the hatchery operators interviewed made a profit.

Among the list of 15 tentative independent variables for multiple regression analysis, the yield of hatchlings from hatcheries was significantly affected ($p < 0.05$) by 3 factors. These were: (1) total volume of weis tanks used for hatching; (2) number of spawnings per breeder per year; and (3) costs of chemicals and medicine.

Yen (2007) reported the average total volume of weis tanks in tra hatcheries to be 150 litres, and that this was sufficient for the continuous operation of hatcheries throughout the year. In the present study, total average volume of weis tanks was larger (290.4 litre per hatchery), suggesting that owners had increased hatchery capacity to meet growing demand for tra seed. IN our study, the results from multiple regression analysis shows that in 2007-2008 the total volume of weis tanks was negatively related to the fry yield. Total volume of weis tanks of about 100-300 litres per hatchery seems to be appropriate (Table 1).

The results of multiple regression analysis also show that during 2007-2008 the number of times female broodfish were spawned each year was positively related to the fry yield. The spawning of individual female brood 5-6 times per year

returned the highest yield and profit per litre of weis tanks per year. Using female broodstock 7 or more times resulted in a slight decline in both the fry yield of and profit (Table 1), as well as the quality of the fry.

Nursery sites of tra fish

Nursery sites averaged 1.1 ha in area, with 3-7 nursing ponds of average water depth of 1.9 m (±0.5), and average stocking density of 545.9 fry/m^2 (±215.4), and average survival rate of 22.3% (±9.5). Nursery sites were operated for a mean 4.6 cycles per year (± 1.5, and ranging from 3 to 10 cycles). The seed were stocked for 59.8 days (±22.4) and the fingerlings were harvested when 1 to 3.5cm. The average total production of each nursery site was 7.581 million fingerlings/ year, but varied quite considerably (±13.591) due to the variable size of operations and other factors such as stocking strategy (large numbers of short stockings or fewer longer stockings). The average yield of fingerlings was 122.5 million fingerlings/ha/year (±75.4).

The average total costs of a nursery site were VND 572.2 million or USD 34,679/ha/year (±366.7), of which variable costs accounted for about 96.2%. The four largest variable cost items included: feed (28.4%), fries and transportation of fries (22.4%), chemicals and drugs (14.2%), and pond preparation (12.6%). The owners earned an average total net income of VND 1,409.4 million or USD 885,418/ha/year but this figure obscures a very strong variation (±VND 1,859.7), in part because 15.4% of the total number of nursery site owners obtained negative profit, and in part due to highly variable nursery size and stocking strategies used.

The results of multiple regression analysis for nursery sites show that the yield of fingerlings harvested depended significantly on five factors ($p < 0.05$). These were: (1) depth of pond water; (2) frequency of water exchange; (3) stocking density; (4) size of harvested fingerlings; and (5) application of best management practices such as those required to attain certification under schemes such as VietGAP, SQF1000, or organic standards.

Above, below: A tra hatchery in the delta.

Fingerling yields in 2007-08 were positively related to the depth of water in nursing ponds. About 27.5% of the total number of nursery sites had the depth of water in ponds equal or higher 2.0 m and these sites obtained highest level fingerling yield but not net income. The water depth of 2.0-2.5 m was most appropriate. Very small or big size of ponds and very deep or shallow level of pond water may cause some difficulties in water and pond management.

Table 1: Factors affecting the yield, production costs and net income of hatcheries.

Variables	Fish yield		Production costs		Net income		Ratio of net income / costs	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Unit	Million fry/litre		VND million / tank/yr		VND million/litre/yr		% year	
Total volume of weis tanks								
< 100 litres	3.1	1.6	3.5	2.3	6.3	3.0	41.8	28.2
100-200 litres	3.0	3.3	3.0	3.0	7.7	4.2	56.5	30.3
200-300 litres	3.8	3.1	3.5	1.9	8.2	4.6	56.8	21.6
> 300 litres	1.8	1.0	1.5	1.5	3.8	3.3	52.4	24.7
Number of times of spawning per brooder/ yr								
≤ 2 times	2.6	0.9	2.6	1.8	5.2	1.8	51.4	28.8
3-4 times	1.9	1.3	2.3	1.3	5.7	4.1	49.8	26.2
5-6 times	5.3	3.6	5.1	2.9	9.3	5.1	46.8	16.1
≥ 7 times	4.2	3.5	3.1	3.7	7.3	4.5	63.7	27.5
Costs of chemicals and medicines								
< VND 0.1 million	1.5	0.9	1.0	0.6	3.5	2.7	54.1	34.3
VND 0.1-0.3 million	2.9	1.8	1.8	1.5	6.2	4.2	67.5	17.5
VND 0.3-0.5 million	1.8	1.3	2.2	1.3	4.5	2.9	40.9	30.1
> VND 0.5 million	4.0	3.2	4.7	2.4	8.8	4.0	45.4	19.8

If the farmers exchanged water daily, about 19% of the total volume of water was exchanged. If water was exchanged every 2 or 3 days, then an exchange rate of about 27% was applied. Daily exchange of water for high stocking density of fry, or exchange every 7 days for low stocking density helped to bring about higher yields, but the highest level net income was observed with the exchange frequency of 3-5 days/time and medium density.

The nursing density from the surveyed sites had a positive relationship with the yield of fingerlings harvested. A nursing density of 500-750 fry/m^2 seemed to be most appropriate for both the yield and net income. However, an increase in the density can lead to a decrease in survival rate, and VINAFISH (2004) recommended a nursing density of just 250-400 fry/m^2.

The size of harvested fingerlings was positively related to nursing duration but negatively related to the numerical yield of fingerings harvested. 45% of the total number of nursery sites harvested fingerlings with a body eight equal to or greater than 2.0 cm. This resulted in a lower yield of fingerlings but a good income level.

Application of best/good practices based on the requirements of schemes such as GAP, SQF1000, or organic standards, was not common at the time of survey due to high costs and complicated management involved, which can directly lead

Table 2: Factors affecting the yield, production costs and net income of the nursery sites.

Variables	Fish yield		Production costs		Net income		Net income : costs	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Unit	1,000 fingerlings / 1000 m^2 pond / cycle		VND million / 1,000 m^2 pond area / cycle		VND million / 1,000 m^2 of pond / cycle		%/cycle	
Water depth of the nursing pond								
≤ 1.5 m	75.0	44.5	10.4	7.6	9.9	12.2	104.5	136.6
1.5-2.0 m	118.9	76.1	16.5	10.9	41.1	63.0	378.6	599.3
2.0-2.5 m	127.7	65.3	11.6	8.4	49.6	48.8	682.3	897.2
≥ 2.5 m	156.3	97.3	11.9	6.0	18.3	15.6	221.8	236.5
Frequency of water exchange								
Every day (1 day/time)	133.3	78.5	13.4	9.2	32.9	41.3	473.1	867.5
3 days/time	87.6	43.3	13.5	8.9	37.1	60.4	369.3	662.2
5 days/time	119.1	63.4	11.8	6.7	45.9	64.3	523.4	611.2
7 days/time	137.4	99.0	13.8	11.2	22.3	22.7	201.5	235.9
Stocking density of hatchlings								
≤ 250/m^2	63.9	44.1	13.4	10.5	34.5	75.8	378.7	820.6
250-500/m^2	111.1	55.1	15.8	9.9	39.4	50.0	436.4	744.6
500-750/m^2	115.9	52.6	11.8	4.1	45.4	48.3	446.2	554.3
≥ 750/m^2	184.6	102.6	7.5	2.8	17.0	13.8	296.4	262.5
Size of the harvested fingerlings (height)								
≤ 1.5 cm	140.2	96.5	10.2	4.6	20.1	43.6	199.4	352.9
1.5-2.0 cm	118.8	69.5	14.3	10.7	35.5	44.1	400.2	498.8
≥ 2.0 cm	102.7	42.7	15.8	10.4	51.9	53.7	665.3	963.5
Application of best/good practices								
No	109.2	47.9	12.0	7.2	40.4	55.5	457.2	562.8
Yes	138.0	97.6	14.5	10.5	27.0	36.0	328.4	723.2

Table 3: Major information on tra catfish grow-out farms.

Description	Inland area	Coastal area	Total of MKD
+ 2 crops / year (%)	67.7	30.2	51.2
+ 1 crop / year (%)	18.9	41.9	29.0
+ 3 crops / 2 years (%)	13.4	27.9	19.8
Farm size (ha/farm)	1.0 (± 1.9)	0.9 (± 1.3)	1.0 (± 1.7)
Stocking density (fish/m^2)	47.2 (± 17.8)	38.7 (± 15.3)	43.5 (± 17.2)
Stocking size (cm)	1.8 (± 0.5)	1.7 (± 0.4)	1.7 (± 0.5)
Survival rate at harvest (%)	77.4 (± 11.8)	74.5 (± 14.8)	76.2 (± 13.2)
Fish yield/ha/year (tonne)	651.3 (± 347.2)	399.4 (± 207.4)	540.4 (±319.1)
Fish yield/ha/crop (tonne)	369.7 (± 164.5)	280.9 (± 128.8)	330.6 (± 156.0)
Total costs/ha/crop (VND million)	4,230.5 (±1,655.6)	3,248.3 (±1,427.9)	3,798.1 (±1,631.7)
Total net income/ha/crop (VND million)	809.9 (±1,044.7)	605.5 (±514.4)	719.9 (±857.6)

to a lower level of net income but better yield of fingerlings. Changing the perception of stakeholders participating in the industry will require improvements in education, a better sector management, and also time.

Grow-out farms (demand side)

Of the 293 grow-out farmers interviewed most (60.3% using multiple responses analysis) were aged 40-60 years. The great bulk practiced (91.5%) based on their own experience, whilst 72.7% also learnt from other tra farmers, and 67.6% had participated in various different formal short training courses. Grow-out farms had a mean pond area of 1.0 ha but there was a great deal of variation (±1.7) due to differences in farm size and the area of land available for pond construction. Most (57.3%) farms comprised of a single pond, whilst 36.2% and 6.5% of farms operated 2-4 ponds and more than 4 ponds, respectively. This indicates that most grow-out farms are small in terms of surface area and number of ponds.

About 51.2% of the surveyed farmers stocked tra fish two crops/year, 29% conducted only one, whilst 19.8% cultured three crops in each two year period. Most farmers growing two crops per year were located inland (67.7%), whereas the other two types of stocking were more common in the coastal provinces.

Grow-out farmers often bought the tra fingerlings from middlemen (45.7% of the total number of fingerlings stocked) and or directly from nursery sites (38.5%). Fingerlings were mainly purchased between March and May (38.5% of the total number of farms) and between July and September (37.8%). Long body, bright colour, uniform size, and good feeding behaviour as well as high survival rate of fish were considered as important indicators of quality by grow-out farmers.

Average stocking density in ponds was 43.5 fingerlings/m^2, with a survival rate of 76.2%. Farmers in inland provinces stocked 47.2 fingerlings/m^2 (±17.8), whereas in coastal provinces tended to stock at a lower density (38.7 ± 15.3 fingerlings/m^2). All of the tra seed used in coastal provinces originated from hatcheries and nurseries in provinces upstream, especially Dong Thap and An Giang. The results from study of Sinh et al. (2006) show that the following factors are important and should be given more emphasis by tra fish grow-out farmers: (1) seasonality, (2) source of seed, (3) stocking density, (4) size of seed, (5) price of seed, (6) checking and screening of seed, and (7) pre-treatment of seed.

This study in 2007-08 revealed that the stocking density of 60-75 fingerlings/m2 (1.2-2.0 cm in height) was optimal in terms of both yield and net income but the environmental impacts must be considered. The results from multiple regression analysis helped to show that there were six factors affecting the density of tra fish stocked in grow-out farms. These were: (1) size of fingerlings; (2) quality of fingerlings; (3) depth of pond water; (4) frequency of water exchange; (5) location of the farms; and (6) application of best/good practice guidelines. The effects of each factor are as follows:

- Size of fingerlings upon stocking is negatively correlated to stocking density. Fingerlings of 1.2-2.0cm height (at which size they weigh between approximately 7 and 33g per individual), and nursed for a duration of 2-2.5 months yielded the best results.
- Quality of seed: better yield and income, medium and good quality of seed was more acceptable while high quality seed might go in hand with higher density and more costs.
- Water depth in grow-out pond is positively correlated to stocking density, and a depth of 4-5 m is most appropriate.

Figure 1: Marketing channels of catfish in the Mekong Delta (2007-08).

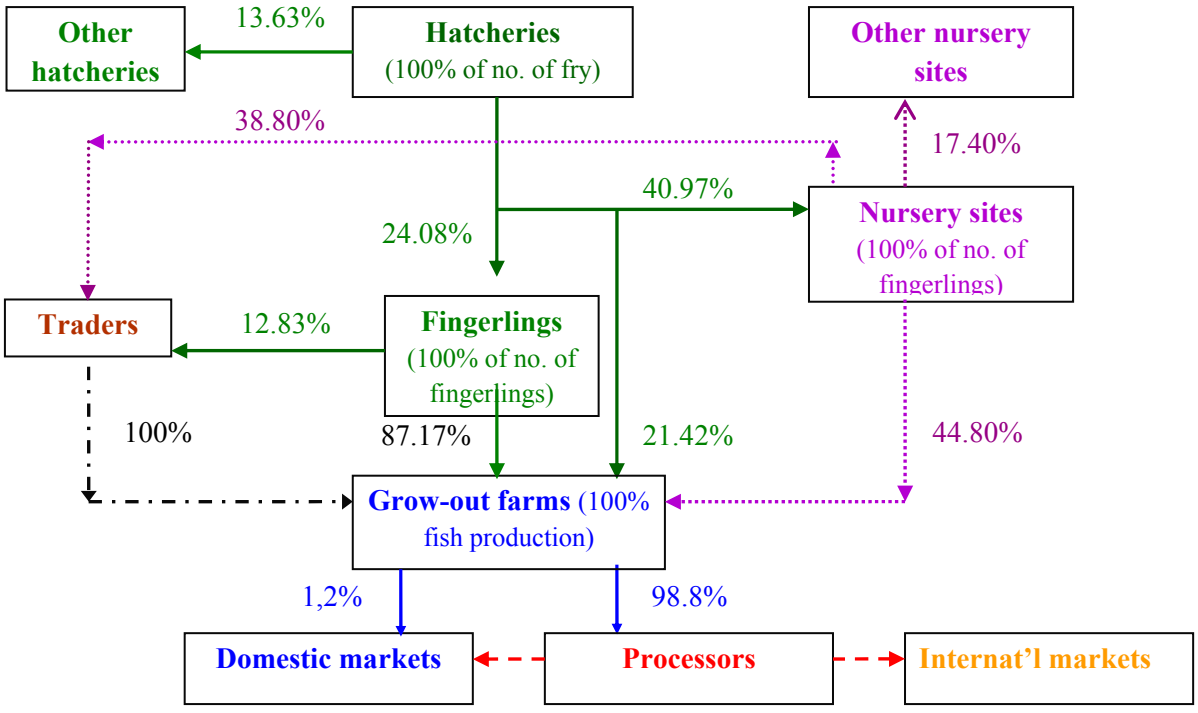
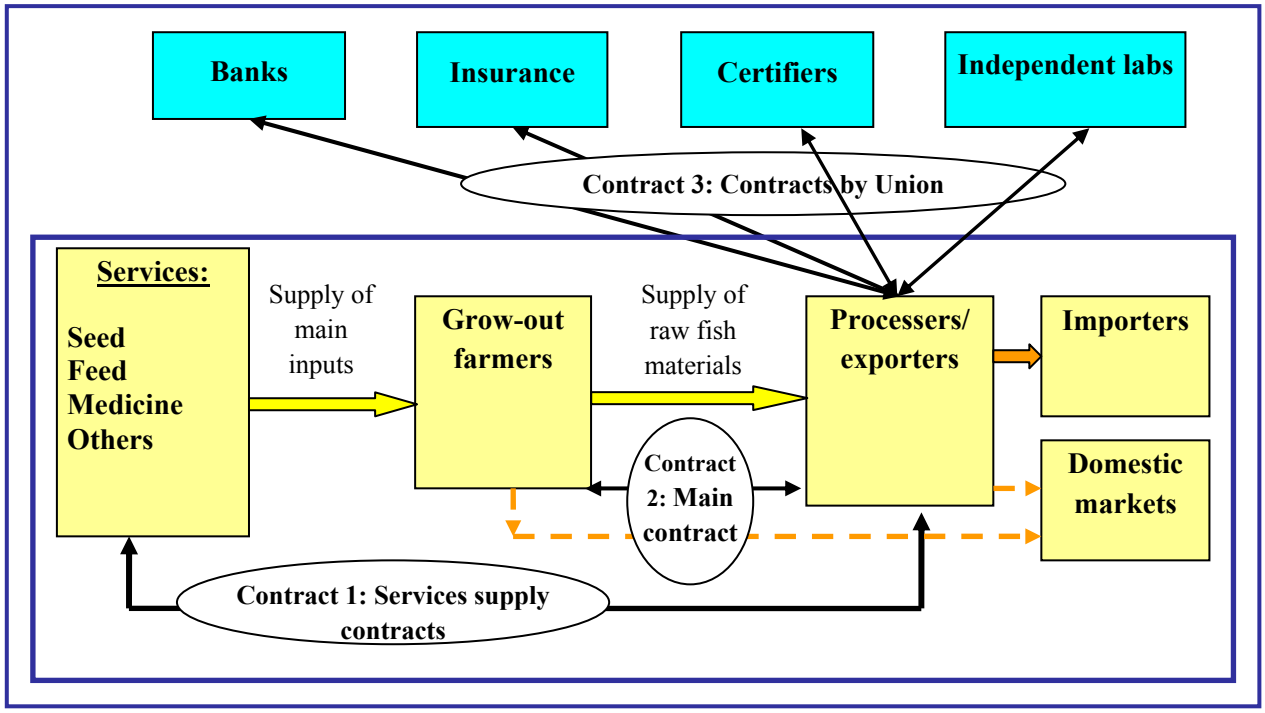


Figure 2: Suggestion for the development of horizontal linkage of Pangasius industry in Vietnam (Revised from the diagram of Nguyen Huu Dung, 2008).



- Exchanging pond water at a rate of about 20-30% of the total pond volume every 2-3 days also yielded the best results.
- Farms in inland provinces and close to big rivers were shown to stock fish at highest densities.
- Finally, adherence to best/good practice guidelines such as GAP, GMP, SQF1000 was shown to result in reduced stocking densities.

Mean crop duration was 6.7 months (±0.8), but ranged from 4 to 10 months depending on the size of fingerlings stocked, and availability of capital of the farms, as well as the market price of feeds, and the farm gate value offered by processing plants. Farms in inland provinces harvested at an average yield of 369.7 tonnes/ha/crop, while the average yield for farms in coastal provinces was lower at 280.9 tonnes/ha/crop. The average survival rate of fish across all of grow-out farms was 76.2% (±13.2) and the average size of harvested fish was 1.1 kg/fish (±0.1).

The total cost per ha per crop for farming tra fish in inland areas was VND 4,230 million (±1,655.6) or USD 256,394, higher than that for coastal farms at VND 3,248.3 million (±1,427.9) or USD 196,867. Total net income per ha per crop also followed the same trend, with VND 809.9 million and VND 605.5 million (or USD 49,085 and USD 36,697) for inland and coastal farms respectively. Because of good market condition in 2007 and the beginning of 2008, the rates of unsuccessful farms (those with negative net income) in 2007-08 were respectively 11.6% and 5.4% of grow-out farmers in inland and coastal areas (the average of this rate in previous years was 20-30%, Sinh 2007; even 40% for the crop at the end of 2008).

For further improvement of the management of grow-out farms, factors significantly affecting yields need to be considered. According to the results of multiple regression analysis, these factors are: (1) depth of pond water. Optimal productivity was obtained with a pond depth of 4-5 m; (2) stocking density of fingerlings, for fingerlings of 1.2-2.0 cm in height a density of 45-60 fingerlings/m^2 yielded appropriate results with some environmental concern; (3) efficient use of chemicals/drugs, this is particularly important given concerns about the environmental impacts of tra production and the quality of fish produced; (4) quantity of pellet feed should be 800-1,000 tonnes/ha/crop with FCR about 1.6; (5) quantity of home-made feed, about 900-1,500 tones/ha/crop seemed to be appropriate; (6) stocking duration, a grow-out cycle of 5-7 months, depending on the size of fingerlings, was best; and (7) size of fish at the harvest, individual fish weighing 1.0kg were best because bigger size of fish might help to increase the yield but much higher costs.

Estimation of the supply and demand, and other issues

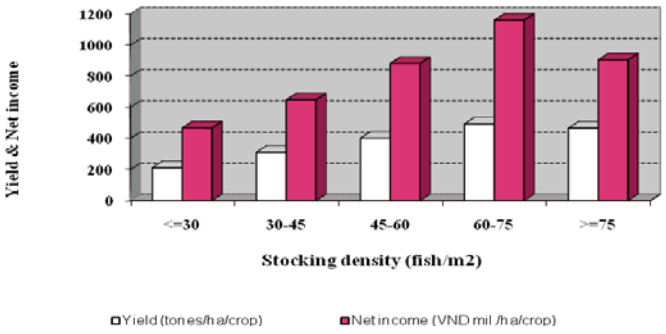
Tra hatcheries can be divided into three groups by capacity and proportion (≤ 300 million fry/year, 36.4%; 300-500 million fry/year, 27.3%; and ≥ 500 million fry/year, 36.4%). Using average production of fry per hatchery a maximum total of 52,953 million of fry could be reproduced by 93 hatcheries in 2007-08. This amount of fry could yield 11,809 million fingerlings. Using the breeder size, number of eggs/kg of breeder, use of breeders and hatching rate can help to estimate the total weight of females needed (about 130-160 tonnes of females per year, plus an extra 20% for replacement).

By the year of 2008, total production of tra fish in the MKD was estimated at 1.2 million tonnes. This amount of fish was produced from farms with a total surface area of just 9,000 ha, of which 6,100 ha is ponds. Combining these figures, with average stocking densities for fingerlings of different sizes, and survival rates during nursing from hatchlings to fingerlings, and grow-out from fingerlings to table-size fish gives an estimated demand for 3.911 billion fingerlings (equal to a total of 23.015 billion hatchlings) in 2007-08.

Decree 102/2008/QD-BNN issued by the Ministry of Agriculture and Rural Development (MARD) of Vietnam approved a development plan for production and marketing of Pangasius catfish in the Mekong Delta to the years 2010 and 2015, and including a vision to 2020. Total cultured area of tra fish are expected to be 8,600 ha; 11,000 ha and 13,000 ha for these years, respectively. It is intended that these culture areas will produce 1.250; 1.650 and 1.850 million tonnes of tra fish, respectively. The total number of tra hatcheries envisioned by the plan for each of these years is 290; 400 and 510. These will be capable of providing, in order, 17; 32; and 51 billion fry or hatchlings.

Comparing estimates of hatchery capacity generated from the data presented in this paper with the MARD catfish development plan therefore reveals that the capacity of tra hatcheries in the Mekong Delta is already sufficient to meet the projected demand for seed for grow-out farms, and may continue to be so even for the next 10 years. Therefore, more careful consideration must be given to ensuring that good hatchery management practices are implemented in order to ensure seed quality, along with timeliness of production, viable prices for producers and users, and effective systems for the distribution of fish seed produced. In addition to the management of seed quality, management of environmental parameters during grow-out and greater attention to the marketing of fish products will also be important.

Figure 3: Stocking density of fingerlings & Yield of table-size fish and Net income



Only 48.5% of the hatchery operators interviewed reported that that they were satisfied with the quality of their broodfish. This statistic may give some cause for concern given that the quality and management of broodfish may impact on the quality and survival of fry or hatchlings which, in turn, may affect the quality and survival rate of fingerlings. These effects may result in the quality of food fish at the harvest. Satisfaction level of nursery site owners on the quality of fry bought was 59.0%. A higher proportion of grow-out farmers (73.6%) reported that the quality of the seed they used for farming was good, although 3.6% thought the fingerlings were of poor quality (Table 5).

These results are perhaps not surprising when few hatcheries, nurseries and grow-out farms follow the best practice guidelines provided by the Ministry of Fisheries for tra culture (e.g. broodfish should be spawned only twice per year; hatchlings should be stocked at a density of 250-400 fry/m^2 for nursing; fingerlings of 10-14 cm in length should be stocked at a density 15-20 /m^2 for growing-out; the depth of water in grow-out ponds should be 2-3 m). Sinh et al. (2006) report that 16.7% of tra grow-out farmers consider government directions on seed and stocking to be important, but that only 4.6% of them follow these directions because of lower yield and net income. This indicates that these

Table 4: Relationship between stocking density, production costs and net income of the grow-out tra catfish farms.

Affecting variables	Fish yield		Production costs		Net income		Net income : costs	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Unit	Tonnes/ha/crop		VND million/ha/crop		VND million/ha/crop		%/crop	
Stocking density of fingerlings								
< 30 fish/m^2	212.5	98.1	2442.9	1045.8	468.1	510.8	14.5	11.8
30-45 fish/m^2	311.0	104.5	3706.6	1238.7	648.3	649.6	14.0	13.4
45-60 fish/m^2	401.8	149.8	4572.6	1401.8	882.4	1090.1	14.2	13.6
60-75 fish/m^2	493.1	167.7	5376.8	1343.6	1159.7	1174.6	15.4	13.1
≥ 75 fish/m^2	466.4	152.8	5649.6	2095.3	906.0	928.1	14.9	13.8
Size of the fingerlings stocked								
≤ 1.5 cm	302.3	152.6	3451.0	1577.6	738.6	881.1	15.7	11.7
1.5-2.0 cm	321.2	140.7	3858.8	1709.1	615.3	673.7	13.1	13.0
2.0-2.5 cm	383.3	166.1	4231.2	1573.0	986.8	1059.9	17.6	12.7
≥ 2.5 cm	329.7	174.6	3653.8	1482.3	609.2	909.9	11.1	14.0

Table 5: Assessment (% farms) on the quality of broodstock, fry and fingerlings.

Assessment	Hatcheries (broodstock)	Nursery (fries)	Grow-out (fingerlings)
Sample size	33	39	280
1- Very bad	-	-	0.4
2- Bad	24.2	15.4	3.2
3- Medium	27.3	25.6	22.9
4- Good	27.3	28.2	46.8
5- Very good	21.2	30.8	26.8

standards are unrealistic and therefore not appropriate to producers. In addition, given the depth of ponds stocking densities are best expressed in cubic meters.

Marketing channels of catfish seed are complex. About 41% of the total amount of fry are sold directly to nursery sites, 13.6% to other hatcheries, and the remainder directly distributed to grow-out farmers or nursed up to fingerlings. Fingerlings produced by nurseries were sold to three main groups of buyers: directly to grow-out farmers (38.5% of the fingerling production), through middlemen (12.8%), and 48.7% to other nursery sites for re-nursing and subsequent resale. About 80% of the nursery sites supported their customers by offering transportation of seed, providing extra fingerlings (usually 1-3% extra) to compensate losses during transport. Fingerling movement, colour, length, uniform size, survival rate were the main concerns of nursery managers.

Even though most fingerlings were traded during the periods March to May, and July to September, there was a lag in the price signals received, meaning that seed prices were highest from April to the beginning of June, and again from August to the beginning of October. The seasonality in both reproduction and grow-out of catfish, should therefore be carefully considered in association with the trends in the export market price of tra when planning for production.

When export market saturation occurred in 2008, many farmers found it necessary to delay harvesting fish for two months or more because they found it impossible to break even given the low farm-gate prices. This is a risky strategy and often results in fish becoming over-sized (more than 1.1kg per fish). In 2007 and 2008, most harvested fish were sold directly to the processors (98.8% of total production). This rate is higher than in the past; that is, 45.6% in 2002 and 81.3% in 2006-07 (Son, 2003; and Son 2007). The decreasing proportion of food fish distributed through the middlemen indicates the increasingly important role of direct supply of raw fish from the grow-out farmers to processing companies. Dung (2008) recommends the establishment and development of vertical linkages in which the processors play a key role and fish is provided by grow-out farmers via direct contracts. Under this type of arrangement processors also have contracts with suppliers of seed, feed, medicines, loans and insurance, and transfer these inputs to grow-out farmers via the farmer-processor contracts. The certifiers of international standards and the independent labs need to be involved. One of the important things is that how to establish and develop concentrated areas for hatcheries and nursery sites as well as for grow-out farms, in which farmers work together in order to improve the investment and operation activities for a better participation in the linkage and to utilize the advantages of a larger scale and also generate synergies.

Conclusions

The design capacity of Pangasius catfish hatcheries in the Mekong Delta is estimated as close to 52 billion hatchlings per year. Using the survival rate of nursery sites, average stocking density of fingerlings, total grow-out areas and number of crops per year, it is estimated that about 36.3% of this total production capacity is adequate to meet current demand for fish seed. However, there are deficiencies in seed supply in terms of quality, time and price. Therefore, appropriate planning, operation and management of the hatcheries and grow-out sectors are important. More consideration should be given to the seasonality of the industry and the training on reproduction and grow-out activities with the application of best practices to ensure production of good quality fish. It should be also said that BMPs/guidelines etc. also have to be updated so that they are more realistic and take into the need to optimise profits and productivity of the farm/nursery/hatchery operations. Provision of better marketing information is also important to both producers and users of fish seed while improvements in the linkages among stakeholders are needed for long-term development of the Pangasius catfish industry in the Delta.

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