Striped catfish farming in the Mekong Delta, Vietnam: a tumultuous path to a global success
Sena S. De Silva¹ and Nguyen T. Phuong²

¹ Network of Aquaculture Centres in Asia–Pacific, Bangkok, Thailand
² College of Aquaculture and Fisheries, CanTho University, CanTho, Vietnam

Abstract
The striped catfish (Pangasianodon hypophthalmus) (Sauvage), also referred to as tra catfish or sutchi catfish, farming sector is an icon of aquaculture development in Vietnam and globally. Over a decade it has developed from a humble backyard operation to one that currently accounts for the production of over one million tonnes, employing over 180 000 rural poor, and generating an export income exceeding US$ 1.4 billion (2010). It accounts for the highest average production, ranging from 200 to 400 t ha⁻¹ crop, ever recorded for the primary production sector. The system is integrated and incorporates seed production, fry to fingerling rearing and grow-out, and is concentrated in a few provinces in the Mekong Delta (8°33′–10°55′N, 104°30′–106°50′E), along two branches of the Mekong River. In essence, perhaps, the initial trade restrictions on catfish exports to the USA provided the impetus and then the associated developments from 2002 to 2005 of the sector to a great extent in seeking new markets. The explosion of tra catfish farming has resulted in many competitive sectors challenging this ‘tra catfish’ invasion into a globalized market. These confrontations still exist with many instances of attempts to discredit the sector and discourage international consumers. However, the Vietnamese catfish sector is resilient and has managed to withstand such pressures and continues to thrive. This paper reviews the development of catfish farming in the Mekong Delta, its current status and what is required to sustain it as a major food source and livelihood provider.

Key words: economic viability, livelihoods, Mekong Delta, rural poor, striped catfish, tra catfish, trade embargoes.

Introduction
The striped catfish (Pangasianodon hypophthalmus) (Sauvage), also commonly known as tra catfish or sutchi catfish, is perhaps the most widely traded fish commodity in the world that originates from a single locality, the Mekong Delta (8°33′–10°55′N, 104°30′–106°50′E), South Vietnam. Production in 2010 amounted to 1 141 000 tonnes, exported to 136 countries across all continents, with an estimated export income of US$ 1.4 billion (Fisheries Directorate 2010). It is also estimated that the sector provides direct employment to over 180 000 people, with the great bulk of this being women, primarily in the processing sector (Fisheries Directorate 2010). To place the catfish farming sector in perspective, the current volume of production is equivalent to approximately 65% of European aquaculture production in 2008 (FAO 2010), but is purported to be carried out in a farming area of <7000 ha.

Much has been written on various aspects of the sector in the recent past, which is to be expected in view of the magnitude of the sector and its socioeconomic importance to the people of Vietnam and the international food fish trade. Some key aspects that have been dealt with are: (i) development trends (Trong et al. 2002; Holland 2007; Neubacher 2007; Nguyen 2007; Nguyen & Oanh 2010); (ii) farming and management practices (Wilkinson 2008a,b; Phan et al. 2009; Bui et al. 2010; Le & Le 2010; NACA 2011); (iii) technological developments (Cacot 1999; Cacot et al. 2002; Crumlish et al. 2002; Tu et al. 2004; Dung et al. 2008; Hao et al. 2004; Sang et al. 2007);
(iv) environmental impacts (Bosma et al. 2009; Anh et al. 2010; De Silva et al. 2010); (v) socioeconomic and policy aspects (Belton et al. 2009; Bush et al. 2009); and (vi) trade issues (Intrafish 2003; Sengupta 2003; Quagraine 2006; Rehbein 2008; Nguyen 2010).

In all of the above instances each issue was treated in isolation. In the context of current global market trends and an overall need to comply with an increasing level of varying standards and certification schemes, this review attempts to trace the overall development of the tra catfish farming sector in the Mekong Delta and suggests approaches to sustain the sector. The review also attempts to place in perspective the obstacles that the sector has had to confront and counteract, and continues to counteract, to remain a leader in global ‘aquaculture’ development, with immense socioeconomic and direct financial benefits to a developing country, while providing a food fish source at an affordable price globally. In this review the farming system under consideration is referred to as the ‘tra catfish’ farming sector throughout.

Historical aspects

Catfish farming in the Mekong Delta is an old tradition, when household, backyard ponds farmed two catfish species, the striped catfish Pangasianodon hypophthalmus (formerly Pangasius sutchi) and the basa catfish Pangasius bocourti, primarily for household consumption and as a means of supplementary income. This practice was also known as ‘latrine fish farming’ because the latrines of the households were located above the ponds, which received human waste. The seedstock for this activity was wild caught, primarily from Cambodian waters of the confluence of the Mekong, Bassac and Tonle Sap Rivers, the main nursery grounds of these catfish species (Nguyen 2009).

This practice gradually began to expand with a transformation into cage and pen (also referred to as fence) culture of the two catfish species in the two main lower branches of the Mekong, Tien Giang (upper) and Hau Giang (lower), which are under the jurisdiction of four provinces, An Giang, Can Tho, Dong Thap and Vinh Long. However, the Cambodian authorities banned the capture of wild stocks in 1994 (Ngor 1999; Nguyen 2009). This ban eventuated a hiatus in the expansion of catfish farming, but lead to a concerted effort to artificially propagate striped catfish, which grew faster than the other two species and was considered to be an ideal candidate for intensive farming.

A breakthrough occurred with the development of artificial propagation techniques for tra and basa catfish (Cacot 1999; Cacot et al. 2002) and the effective dissemination of the techniques to prospective farmers (Davy et al. 2011, in press). The bulk of early catfish farming was in cages and pens and the catfish species were farmed in monoculture and or in polyculture with Pangasius conchophilus (Nguyen et al. 2009). Cage and pen culture activities intensified problems related to water flow in the river, particularly during the summer months, which began to impact on the cage farming, resulting in increased disease occurrence and reduced growth. It has been purported that concurrently very small-scale operators were experimenting with bottom-fixed cages and culture in small ponds with encouraging results, and anecdotal evidence also suggests that the flesh quality of the produce was better (Anonymous 2009). This could have been the advent into pond farming along the lower reaches of the Mekong. The changes in the three basic farming practices of catfish over the period 1997–2007 are depicted in Figure 1. It is clearly evident that there was a relatively rapid transformation into the currently predominant pond culture in the early years of this decade, and by 2007 cage and fence culture of tra catfish was almost obsolete. Now the sector is almost exclusively based on pond culture practices, along two main branches of the Mekong River. Davy et al. (2011, in press) attempted to summarize the main stages in the developments (Table 1) that have led to the current status in the tra catfish farming sector from its very beginning.

Current tra catfish farming practice(s)

Tra catfish farming occupies a rather unique status in global aquaculture. Network of Aquaculture Centres in Asia–Pacific (NACA 2011) recognised the following features as unique to this farming system, which are summarised as follows:

- It is a farming system that is capable of producing on average over 200–400 t ha⁻¹ crop; the highest recorded
for any primary production sector in the world, and it is a farming system that essentially occupies approximately 6000–7000 ha of land.

- It is mainly a pond farming system that is conducted in ponds 4–4.5 m deep, with regular water exchange from the Mekong River and/or its tributaries.
  - It provides many livelihood opportunities to poor rural communities, particularly women.
  - The farming system is blessed with an adequate water supply throughout the year. However, the farming system is obligated to ensure that the water source is not over loaded with nutrients, bringing about negative impacts on all users of this common, valuable resource.
- It is a farming system that for all intents and purposes is vertically integrated, with specialised hatchery production, fry to fingerling/nursery rearing and grow-out phases operating independently and complimenting the large processing sector.
- It is a farming system in which the produce is almost entirely destined for export; tra catfish is an acceptable substitute for ‘white fish’, particularly for the Western palate/taste, thereby catering to a ‘mass’ market.

Current tra catfish farming practices occur in the two main branches, Tien Giang (upper) and Hau Giang (lower), of the lower Mekong River running through Vietnam (Fig. 2). It is also noteworthy that in areas conducive to farming there is a concentration of ponds/farms, but ponds tend to be of similar dimensions (Plate 1).

### Production trends

In general, catfish production began to grow from 2000. Rapid growth was found after 2002–2004, but growth reached a plateau from 2008 to 2010 (Fig. 3). The growth of tra catfish production relates to the change in the production systems, particularly the rapid expansion of the predominant pond culture system. It is evident from Figure 3 that the rapid expansion of the sector was linked to an increase in export volume and a corresponding increase in export income, which in turn was brought about by the emergence of new export markets (see later sections for details).

Overall, small farms dominate in terms of pond area and most are farmer owned or leased, operated and managed (Phan et al. 2009). Based on data from provincial fisheries authorities there were 5393 tra catfish grow-out farms in operation in 2009, of which there were 4416 farms of <1 ha water surface (81.9%), 812 farms from 1 to 5 ha water surface (15.1%), and 165 farms with a water surface >5 ha (3.1%).

However, there has been an increase in large-scale farms, which are mostly owned and operated by processing companies; a trend that appears to be encouraged by the authorities (Prime Ministerial Decree: No 2033/QD-TTg). In contrast, the number of small-scale farms has decreased because of many factors, including a drop in farm gate price leading to economic losses and an inability to increase investment. However, small-scale farms still remain dominant in the sector, an aspect that is dealt with in detail later in this review.

### Integration of production units (seed/nursery/grow-out)

There is a division of labour in the different steps of the production system, that is, fry production (hatchery operations), fry to fingerling and grow-out operations, resulting in a degree of vertical integration. There is also an apparent geographical element in this integration. For example, seed production hatcheries are mostly located in Dong Thap and An Giang provinces, with fry to fingerling rearing in Dong Thap, An Giang and Can Tho provinces and grow-out farms distributed throughout all

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**Table 1** Timeline of tra catfish grow-out development (reproduced from Davy et al. 2011, in press)

<table>
<thead>
<tr>
<th>Date</th>
<th>Important change events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940–1950</td>
<td>Tra catfish culture in small, family ponds using wild-collected fingerlings commenced in An Giang and Dong Thap provinces, which are upstream of the Mekong River Delta in Vietnam</td>
</tr>
<tr>
<td>1981–1982: trials of pond culture</td>
<td>First trials of tra catfish intensive culture in small ponds conducted by a farmer in Can Tho city using wild-caught fingerlings</td>
</tr>
<tr>
<td>1996–1999: expansion of pond culture and trials of cage culture</td>
<td>Tra catfish intensive culture in ponds expanded gradually to other provinces. First trials of tra catfish culture in cages (replacement of basa catfish) and pens were also conducted. Both production systems used wild and hatchery-reared fingerlings</td>
</tr>
<tr>
<td>2000–2004: rapid expansion of cage and pond culture</td>
<td>Tra catfish intensive culture in cages and ponds expanded rapidly. Hatchery-reared fingerlings met the demand for stocking. Productivity was significantly improved. Farmers gradually shifted from homemade feeds to commercial feeds</td>
</tr>
<tr>
<td>2005–to present: increase in productivity</td>
<td>Collapse of tra catfish cage and pen culture occurred. There were significant improvements to pond culture techniques and marked increases in productivity. Introduction of sustainable production standards such as SQF-1000, AquaGAP, GlobalGAP and BMPs.</td>
</tr>
</tbody>
</table>

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provinces (see Fig. 2). The tra catfish farming sector is integrated with specialized sectors for seed production, fry to fingerling rearing and grow-out (Fig. 4). This integration has evolved over the years, perhaps enabling the sector to function more efficiently, with specialization of each of the component practices. This integration may also help in the effective dissemination of new technologies for each of the components.

Seed production and broodstock management

The development of artificial propagation of tra catfish (Cacot 1999; Cacot et al. 2002) and the dissemination of the techniques throughout the Mekong Delta in a very effective manner has in all probability been the main trigger (Table 1) that has enabled the sector to develop rapidly (Davy et al. 2011, in press). The hatcheries operating in the Mekong Delta range from ‘backyard’ to commercial-scale operations; the former are located essentially in a room in the farmer’s household (Plate 1).

Bui et al. (2010) surveyed 45 tra catfish hatcheries in Dong Thap, An Giang and Can Tho provinces and reported that the size of the hatcheries ranged from 0.2 to 15 ha (2.5 ± 0.5 ha), with 0.05–10 ha (1.59 ± 0.3 ha) under water. According to Bui et al.’s (2010) study, most hatcheries tended to maintain a large number of potential brood fish (350–29 200; 8042 ± 805), of which only a small proportion were considered to be broodstock and used in any 1 year (240–11 300; 4100 ± 454). The mean weight of male and female broodstock ranged from 0.5 to 8 kg and 0.5 to 12 kg, respectively, maintained at a ratio of 0.05–1.0 (0.34 ± 0.03). Spawned fish were at least 1.75 kg (female) and 1.5 kg (males) and spawning was induced by injection with Human Chorionic Gonadotropin (HCG). On average females received four or five doses at a time (dose averages were 542, 597, 893 and 3442 IU kg$^{-1}$; injected at 0, 23, 46, 56 and 66 h), and ovulation occurred 5–11 h after the last injection (at 28–29°C). Eggs were incubated in hatching jars (Zoug jars and Weis-shaped incubators) (6–200 L volume, mean 40 L) and stocked at 0.02–1.5 kg eggs L$^{-1}$ (0.23 ± 0.04 kg eggs L$^{-1}$). Bui et al. (2010) also reported the following quantitative relationships:

Eggs kg$^{-1}$ (mil.) = 0.151 – 0.015 × female weight (kg) 
(P = 0.006, Adj. $R^2$ = 0.179)

Larvae kg$^{-1}$ (mil.) = 0.108 – 0.012 × female weight (kg) 
(P = 0.006, Adj. $R^2$ = 0.182)

Le and Le (2010) reported that there were 93 tra catfish hatcheries in the Mekong Delta, mostly located in An Giang and Dong Thap provinces. These hatcheries have a capacity to produce 818.3 million hatchlings per year, and most hatcheries optimally operated from February to June, when 29.8 production cycles year$^{-1}$ were obtained;
the duration of each was approximately 7 days. Le and Le (2010) estimated that a total of 52 million tra catfish fry were produced in 2007–2008, and that on average hatchery owners gained a total net income of VND 802 million year\(^{-1}\) (≈US$ 48,618), but there was high variability in the net income among hatcheries (VND ± 798.2). According to Khiem et al. (2010) hatchery operations tend to be more profitable than nursery and grow-out operations.

Le and Le (2010) also noted that a number of factors impacted on the yield of hatchlings and provided details of the costs and net income for tra catfish hatcheries (Table 2). Bui et al. (2010) also reported that during 2008, hatcheries produced 3–200 (mean 38) batches of spawns, using 2–90 (mean 21) males and 1–240 (mean 65) females per batch; each male and female may be used up to 20 (mean 2.7) and five (mean 2) times each year, respectively. On this basis, each hatchery used 30–6333 (511 ± 193) males and 19–6000 (1217 ± 233) females in 2008.

Belton et al. (2010b) reported that most hatcheries sourced their broodstock from their own extensive grow-out facilities, as also reported by Bui et al. (2010), when a large number of fish were maintained. Potential broodstock for spawning were selected from these large stocks and weaned to a pellet feed and conditioned for spawning. In some districts, for example, in Tan Chau, hatchery operators preferred to use wild-caught broodstock. In contrast, one study (Bui et al. 2010) found that broodstock of farm origin produced up to 30% more eggs than wild caught fish, and that the eggs had a higher hatching rate.

According to Bui et al. (2010), broodstock are generally discarded when they reach 10 kg in weight because of difficulties in handling or when relative productivity is <5% for females, and many hatcheries (67%) recruit new broodstock on a regular basis. The frequency at which fish were replaced ranged from every year to every 10 years (mean 3 years), with <1–68% (mean 7%) of resident stock being replaced every year. New broodstock are obtained from the farm’s own stock (47%), other grow-out farms (53%) or from the wild (20%).

It is clear that broodstock management aspects vary widely among tra catfish hatchery operators; procurement, usage and discarding of individual fish is done on
a relatively ad hoc basis, based on the experience of the operators. The tra catfish sector, however, differs significantly from other cultured finfish sectors, in that large numbers of potential broodstock are maintained and fish selected from this stock are conditioned before spawning. It has been suggested that this practice may be rather wasteful and that it needs to be reviewed using modern broodstock management principles (Nguyen 2009).

In a sector that is growing fast and with increasing restrictions coming into place with regard to the procurement of wild broodstock (Nguyen 2009), which are mostly found in Cambodian waters, there is a need for a concerted effort to put into place long-term broodstock management plans using modern genetic knowledge. A recent study by Ha et al. (2009) revealed that there was no genetic differentiation between hatchery and contemporary wild populations of striped catfish (*P. hypophthalmus*), perhaps reiterating the suggestion that existing stocks could be used to put into place a scientifically based broodstock management plan, and to use such stocks for genetic improvement through selective breeding for traits that are desirable. Work on this latter aspect is progressing to some degree (e.g. Hao et al. 2004).

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It has been pointed out that with the expected sea level rise in the Mekong Delta, as a result of climate change, there will be seawater intrusion further upstream (e.g. Khang et al. 2008; Southern Institute for Water Resources Planning 2008). This together with the expected reduction in river water flow will result in salinity increases in the lower reaches of the river, even into areas where catfish farming currently occurs. In this context De Silva and Soto (2009) have proposed that selective breeding programs be developed to produce strains of tra catfish that are more tolerant to increased salinity; this is the most appropriate and pragmatic adaptation to safeguard the livelihoods of tra catfish farmers downstream in the Mekong river.

**Table 2 Factors affecting the yield, production costs and net income of hatcheries (modified after Le & Le 2010)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Fish yield</th>
<th>Production costs</th>
<th>Net income</th>
<th>Ratio of net income/costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Unit total volume of Weis tanks (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;100</td>
<td>3.1</td>
<td>1.6</td>
<td>3.5</td>
<td>2.3</td>
</tr>
<tr>
<td>100–200</td>
<td>3.0</td>
<td>3.3</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>200–300</td>
<td>3.8</td>
<td>3.1</td>
<td>3.5</td>
<td>1.9</td>
</tr>
<tr>
<td>&gt;300</td>
<td>1.8</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>No. spawns per brooder per year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤2</td>
<td>2.6</td>
<td>0.9</td>
<td>2.6</td>
<td>1.8</td>
</tr>
<tr>
<td>3–4</td>
<td>1.9</td>
<td>1.3</td>
<td>2.3</td>
<td>1.3</td>
</tr>
<tr>
<td>5–6</td>
<td>5.3</td>
<td>3.6</td>
<td>5.1</td>
<td>2.9</td>
</tr>
<tr>
<td>≥7</td>
<td>4.2</td>
<td>3.5</td>
<td>3.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Costs of chemicals and medicines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;VND 0.1 million</td>
<td>1.5</td>
<td>0.9</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>VND 0.1–0.3 million</td>
<td>2.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td>VND 0.3–0.5 million</td>
<td>1.8</td>
<td>1.3</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>&gt;VND 0.5 million</td>
<td>4.0</td>
<td>3.2</td>
<td>4.7</td>
<td>2.4</td>
</tr>
</tbody>
</table>

SD, standard deviation.
The great majority of nursery farms use live (Moina) or natural feed and soybean meal, soybean milk or egg, in the form of an emulsion for larval rearing for up to 1–30 (7 ± 1) days of the culture period. Nursery farms (96%) also tend to use commercial feeds, particularly in the latter stage of the culture cycle mainly for its convenience (easy to manage, use and store), effectiveness (growth and healthy fish) and quality. Farmers that used farm-made feed stocked fry ponds at a significantly (P < 0.05) higher density (497 ± 188 fish m⁻²), but had a significantly (P < 0.05) higher mortality rate in the fry-to-fingerling stage (52 ± 10%) than those farms that did not use farm-made feed (stocking density 154 ± 55 fish m⁻², mortality rate 29 ± 6%). The feed rates and feeding frequencies used by farmers varied widely, ranging from 5 to 18% per body weight per day, and 4–8 times per day, respectively (Bui et al. 2010).

Bui et al. (2010) also reported that the relationships between fry and fingerling size (length) and body depth at harvest were highly correlated (P < 0.05) for both fry and fingerlings:

\[
\text{Fingerling depth (cm)} = 0.80 + 0.07 \times \text{fingerling size (cm)} \\
(P = 0.0006, \text{Adj. } R^2 = 0.44)
\]

\[
\text{Fry depth (cm)} = 0.35 + 0.09 \times \text{fry size (cm)} \\
(P = 0.009, \text{Adj. } R^2 = 0.54).
\]

Although fish kg⁻¹ at harvest was significantly correlated with the size of the fry (fish kg⁻¹ = 272–303 × fry size (cm); P = 0.0006, Adj. R² = 0.68), it was not correlated with fingerling size (P > 0.05).

Some of the general features of hatchery and nursery activities, and the production costs and selling price at each point are summarised in Table 3.

Stocking densities used during transport (early hatchlings) ranged from 200 to 50 000 (8378 ± 1398), from 100 to 40 000 (7314 ± 5581) and from 1 to 400 (164 ± 73) individuals L⁻¹ for larvae, fry and fingerlings, respectively. Fish could be in transit for up to 25 h (mean 6 h). At purchase (Bui et al. 2010) fry are 0.2–6.7 g in weight (mean 0.45 g) (150–5000 fry kg⁻¹, mean 2100 fry kg⁻¹). At this size fry have a body depth of 0.1–1.5 cm (mean 0.7 cm).

**Grow-out**

A comprehensive study was conducted by Phan et al. (2009) on grow-out farming practices of tra catfish in the Mekong Delta. This study dealt with pond size and distribution, stocking densities, farm operations including water usage, food and feed management, production, disease occurrence, harvesting and marketing, aspects of the farming communities and economic viability.

Phan et al. (2009) found from their survey that 72% of farms were < 5 ha, and only 9% were 10 ha or greater in size. Bush et al. (2010) found that of all the farms surveyed in An Giang province, a major area of tra catfish farming, most were <5 ha. Thus, catfish farming in the Mekong Delta can be categorised as primarily based on relatively small holdings that are farmer owned, operated and managed, as is the case for shrimp farming in Thailand (Kongkeo 1997) and India (Umesh 2007), and generally in aquaculture in Asian countries, such as Thailand (Ministry of Agriculture and Cooperatives 2006) and China (Ministry of Agriculture 2007).

Catfish farms tend to be rather different from other aquaculture sectors in Asia in that individual pond depth ranges from 2.0 to 6.0 m, with the great majority of farms

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**Table 3** Production characteristics for larvae-to-fry and fry-to-fingerling culture phases for catfish nursery farms together with the cost of production (including chemical and labour costs) and the selling price of seedstock for hatcheries and nursery farms

<table>
<thead>
<tr>
<th></th>
<th>Larvae-to-fry</th>
<th>Fry-to-fingerling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stocking</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (days old)</td>
<td>1–2</td>
<td>NDA</td>
</tr>
<tr>
<td>Stocking density</td>
<td>71–8000</td>
<td>15–1166</td>
</tr>
<tr>
<td>(m⁻²)</td>
<td>(855 ± 192)</td>
<td>(279 ± 79)</td>
</tr>
<tr>
<td>Stocking density</td>
<td>100–1000</td>
<td>25–583</td>
</tr>
<tr>
<td>(m⁻³)</td>
<td>(374 ± 54)</td>
<td>(166 ± 56)</td>
</tr>
<tr>
<td>Culture period (days)</td>
<td>20–45</td>
<td>20–120 (57 ± 3)</td>
</tr>
<tr>
<td></td>
<td>(27 ± 1)</td>
<td></td>
</tr>
<tr>
<td><strong>Harvest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production (millions)</td>
<td>0.04–1800</td>
<td>0.02–60 000</td>
</tr>
<tr>
<td>fish farm⁻¹ year⁻¹</td>
<td>(79 ± 75)</td>
<td>(1671 ± 1667)</td>
</tr>
<tr>
<td>Yield (millions)</td>
<td>0.3–4.65</td>
<td>0.25–1.30</td>
</tr>
<tr>
<td>fish ha⁻¹ crop⁻¹</td>
<td>(1.22 ± 0.35)</td>
<td>(0.69 ± 0.08)</td>
</tr>
<tr>
<td>Mean size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish size (cm)</td>
<td>0.5–8.5</td>
<td>1.2–20</td>
</tr>
<tr>
<td></td>
<td>(4.5 ± 0.7)</td>
<td>(8.6 ± 0.9)</td>
</tr>
<tr>
<td>Fish depth (cm)</td>
<td>0.3–2.0</td>
<td>1–3</td>
</tr>
<tr>
<td></td>
<td>(0.9 ± 0.1)</td>
<td>(1.5 ± 0.1)</td>
</tr>
<tr>
<td>Tails kg⁻¹</td>
<td>80–4000</td>
<td>11–1000</td>
</tr>
<tr>
<td></td>
<td>(1728 ± 243)</td>
<td>(134 ± 25)</td>
</tr>
</tbody>
</table>

Production cost/selling price (VND fish⁻¹)

<table>
<thead>
<tr>
<th></th>
<th>Production cost</th>
<th>Selling price</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hatcheries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larvae</td>
<td>0.2–7.0 (0.96 ± 0.18)</td>
<td>0.2–18 (2.85 ± 0.26)</td>
</tr>
<tr>
<td>Fry</td>
<td>23–70 (37.6 ± 4.4)</td>
<td>23–150 (58 ± 4.5)</td>
</tr>
<tr>
<td>Fingerlings</td>
<td>100–650 (282 ± 70)</td>
<td>100–1400 (387 ± 110)</td>
</tr>
<tr>
<td>In nursery farms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fingerlings</td>
<td>4–700 (199 ± 32)</td>
<td>10–1200 (243 ± 34)</td>
</tr>
</tbody>
</table>

Values represent ranges with mean ± standard error in parentheses (VND 17 500 = US$ 1). Modified after Bui et al. (2010). NDA, no data available.
having pond water depths of 3.5–4.5 m. Nguyen and Dang (2009) suggested that this practice came about through the necessity of preventing stock from escaping during the flood season into the main river, and therefore needing a higher dike than normal. Wide ranges of stocking densities have been reported, ranging from 18–125 fish m$^{-2}$ [48 ± 2.1, mean ± standard error (SE)] to 5–31 fish m$^{-3}$ (12 ± 0.5); stocking density depended on the size and availability of seedstock and the financial capacity of the farmers to purchase seedstock.

Phan et al. (2009) reported that farm yields ranged from 70.0 to 850 t ha$^{-1}$ crop$^{-1}$ (406 ± 16, mean ± SE). These authors also discussed the reasons underlying the wide ranges in yield. This production equated to 1.5–22.7 t megaL$^{-1}$ crop$^{-1}$ (10.4 ± 0.4), and furthermore the frequency distribution of the yield in t ha$^{-1}$ crop$^{-1}$ corresponded to a normal distribution curve, where 76% of the farms yielded 300 t ha$^{-1}$ crop$^{-1}$ or more. The authors suggested that very low yields occurred in a few farms as a result of unforeseen mortalities, generally early in the growth cycle, and conversely yields above 550 t ha$^{-1}$ crop$^{-1}$ were obtained when farms tended to hold the stocks until acceptable market prices were realised. These findings are consistent with those of the Institute for Fisheries Economics and Planning in Southern Vietnam (2009) that reported yields of 200–400 t ha$^{-1}$ crop$^{-1}$. If the trend in production for tra pond culture over the years is taken into consideration it is evident that average production amounts to approximately 200 t ha$^{-1}$ crop$^{-1}$ (Fig. 5). Importantly, overall there has been a gradual increase in pond culture area, in particular from 2000 to 2003 onwards, and a corresponding marked increase in production per unit area over the years up to the current level (Fig. 5).

Interestingly, Phan et al. (2009) attempted to compute the water consumption related to tra catfish production. This is an important and relevant area as the sector’s high production is impacted by the fact that high flushing rates are maintained, permitting heavy stocking and feeding. The results showed that farm water volume and water exchange rates were highly skewed and ranged from 0.7 to 59.7 megaL t$^{-1}$ (6.4 ± 0.8, mean ± SE) or 0.017–1.412 T megaL$^{-1}$ (mean 0.292 T megaL$^{-1}$). This level of water consumption is much lower than that used in shrimp farming in ponds (11–43 megaL t$^{-1}$) and in the tank culture of salmonids (252 megaL t$^{-1}$) (Beveridge et al. 1991). Phan et al. (2009) proceeded to estimate the total water consumed in 2007 based on 683 000 t of catfish production in the whole of the Mekong Delta. The final estimate was that 4371 gigaL of water was used, of which 2754 gigaL was discharged back to the river, and that the amount of water used for the production of a tonne of catfish was 4023 m$^3$, approximately 10% higher than the estimates of Bosma et al. (2009).

Disease aspects

Diseases are a major concern for the sustainability and profitability of the tra catfish farming sector in Vietnam. Although there has been significant improvement in our understanding of diseases in the tra catfish farming sector in recent years, there is a need for more research and development work in this regard, particularly as the emergence and spread of disease has greatly increased over the past few years, along with the rapid expansion and intensification of the sector.

Common pathogens that have been reported to be associated with diseases in tra catfish culture, including parasites and bacteria, have been documented (Dung et al. 2008; Nguyen et al. 2008; Ly et al. 2009). Among the infectious diseases, bacterial agents have been responsible for the major epizootics affecting tra catfish farming. Losses resulting from bacterial diseases have been estimated to be as high as 50% compared with other diseases (Nguyen et al. 2004; Nguyen TP et al. 2007). Bacillary necrosis of Pangasius (BNP) caused by Edwardsiella ictaluri (Crumlish et al. 2002) is considered to be the most virulent disease occurring in catfish farms. This disease has had an increasing impact over time and has been reported to cause mass mortality of stocks in some cases (Tu et al. 2004). There has been limited treatment available for BNP (Dung et al. 2008). Haemorrhage disease, which is caused by multiple infectious bacterial agents, has also been a significant cause of mortality in tra catfish farms (Ly et al. 2009). This disease has been characterized by internal organ necrosis, white (spot) nodules in the liver, kidney and spleen, and petechial haemorrhages on the tail, fins and abdomen. Outbreaks of this disease have been reported to be associated with stress-induced factors, including environmental degradation, high stocking

![Figure 5](image-url)
density and low-quality stocked seed (Nguyen TP et al. 2007).

Phan et al. (2009) reported that the occurrence of clinical signs/diseases in tra catfish farming was highest in June and July, which corresponds with the onset of the wet season and increased rainfall. Despite limited disease information, the growth of the tra catfish industry had been so rapid that population-based research has not been able to identify key risks to tra catfish culture and develop appropriate management interventions. As a consequence, there is a lack of available epidemiological data to fully understand the primary infectious agents involved in the mortality of catfish and the triggering factors in the farms, and this warrants urgent attention.

**Growth of exports of tra catfish**

The export of catfish from Vietnam began in the 1990s, albeit on a very small scale. In the early stages the main exported species was *P. bocourti* (basa) because at that time tra catfish production had not developed. The main and only market in the 1990s was the USA (Nguyen 2008). However, export of catfish grew rapidly when production of tra catfish was initiated around 2000 and the export market also diversified; currently (in 2010) catfish are exported to 136 countries (Fig. 6; also see Fig. 3). Figure 6 shows that there was a rapid growth of tra catfish exports from 2002 to 2003 onwards; this growth was almost exponentially and reached a plateau around 2008.

There have been significant changes in the export markets over the years (Fig. 7). Recently, the European Union (EU) has become the most important market for tra catfish, accounting for 37–40% of the total exports, whereas catfish numbers to the USA have declined markedly (Fig. 7). New markets have emerged, such as Russia together with many other countries, which are categorised under ‘others’ in Fig. 7; these new markets currently account for 35–40% of tra catfish exports.

The trade restrictions that limited exports to the USA and the resulting strategy of the Government of Vietnam to explore alternative markets, successfully, were perhaps determining factors for the upsurge of the tra catfish farming sector. The trade restrictions and the resultant litigation in a manner flagged a relatively unfair action and provided much publicity to tra catfish in the global market place, elements that were exploited to the fullest by the Government of Vietnam and related authorities. Importantly, in the wake of the trade restrictions, the Government of Vietnam did not take steps to limit production, but on the contrary encouraged the sector to increase production, perhaps because of the conviction that new markets could be developed. This gamble appears to have paid off. Details on these aspects are dealt with later in our review.

**Growth in the processing sector and support services**

The increasing volume of exports has to be met with an increase in the processing capacity as well as in production; the latter requires improved services, such as the
availability of feed. Consequently, the numbers of processing units and the available capacity have increased rapidly, particularly in 2008 (Fig. 8). The proliferation in the number of processing units coincided with the export volume, a surge occurred from 2005 onwards, and currently there are almost 140 units operating with a cumulative capacity of nearly one million tonnes of processed product; that is, with a capability of handling approximately two million tones of fresh fish.

All tra catfish processing units are privately owned and most are located in provinces of the Mekong Delta in close proximity to the grow-out farms, that is, in Can Tho city, An Giang province and Dong Thap provinces. The available information suggests that all tra catfish processing units are International Standards Organization (ISO), Hazard Analysis and Critical Control Point (HACCP), and European Union (EU) certified and comply to the highest levels expected of present day food quality and safety.

There has been rapid growth in other services needed to cater for the increased export demand for tra catfish. Most notable among these has been the growth of the feed production sector. For example, in 2008 there were 54 feed mills operating that exclusively catered to the tra catfish farming sector, with a capacity of 5 847 000 tonnes, but which produced only 2 240 000 tonnes. Figure 9 depicts the number of feed mills in relation to potential capacity. It is very evident that most feed mills have a capacity of <40 000 t year\(^{-1}\). This wide range in capacity of the feed mills, with the majority being relatively small, perhaps permits this subsector to retain a degree of resilience in relation to the demand for feed.

### Integration of post-production steps in the value chain

As well as integration in the production sector, there is an equally important integration along the value chain (see Fig. 11), making the tra catfish farming sector one with a high degree of uniqueness. Although only a few large processing companies operate farms, these ventures still have to rely on fresh supplies from small-scale farming activities to meet processing capacity needs.

As such, along the value chain there are specialised units with, for example, crews of up to 10–20 for harvesting on a contract basis. These crews move to farms on demand and are responsible for harvesting and transferring the harvest to boats for river/canal transportation, live, to the processing plants. Each boat, often family operated, has the capacity to carry 40–60 t of live catfish at a time. The boats are modified to retain water in the hull, but allow exchange throughout the transportation through small (approximately 20 × 8 cm) netted apertures right around the hull. This constant exchange of water allows the fish to be maintained in good condition until delivery to the processing plants. Here again, transportation of harvested catfish is a specialised sector (distances of transportation range from 2 to approximately 8 h maximum) that is carried out on a contract basis.

It is rather unfortunate that no studies have examined these subsectors. It is thought that these subsectors, apart from providing many livelihood opportunities and income generation avenues, also contribute significantly to overall societal gains and well-being.

### Economic aspects of the tra catfish sector

The catfish farming sector, although mostly generating significant incomes for the communities and the country, operates economically at very marginal profit levels, perhaps enabling the farmers, particularly small-scale farmers, to remain economically viable because of the large volume of production.

Nghe (2010) reported, for example, that in the first 5 months of 2010 the gross output of the sector was...
248 834 tonnes (filleted fish) with a value of US$ 533 million, an increase of 19.4 and 11.6%, respectively, over the same period in 2009. However, the author noted that this increase in value did not equate to increased output owing to a decrease in average fish price (fillet) from US$ 2.28 in 2009 to 2.13 kg\(^{-1}\), this in turn was reflected in the farm gate price. Such economic hardship has lead catfish farmers, particularly small-scale farmers who represent a significant proportion of the producers in the sector, to often suspend farming until the farm gate prices attain an economically viable level. Hong (2010) similarly reported that the area of tra catfish farming in CanTho decreased by 60% in the early part of 2010, and in Dong Thap province the farming area decreased by 700 ha (from a total of 1100 ha); similar decreases also occurred in other provinces. According to Hong (2010) on average the suspended pond area amounted to approximately 40%.

 Obviously a high intensive farming system, such as the tra catfish farming sector, tends to generate high revenues and can bring high profits to all stakeholders along the value chain. As pointed out by Le and Cheong (2010), such systems, however, also bring about high risks, in particular to the producers, with factors such as price fluctuations arising from oversupply and market demand and yield losses from diseases impacting on the profits. These authors demonstrated that the farm gate price of catfish decreased in real terms (1994 constant price) over the period 1997–2008 from approximately VND 6000 to 4200, which was also impacted by high inflation rates in Vietnam.

 The average farm gate price of tra catfish together with the export price of the processed product over the years is shown in Figure 10. It is evident that the former has increased marginally over the years, but the latter has in effect declined, significantly, over the same period of time. This raises the question: how have catfish processors and farmers remained economically viable?

Surprisingly, however, there have been very few studies conducted on the economics per se of the different stages of the value chain. Based on a survey of 97 tra catfish farms, Phan et al. (2009) reported that the investment cost of a catfish farm is relatively large and deviates greatly from farm to farm. Overall, fixed costs range from VND 7 million to 15.23 billion (US$ 1 ~ VND 15 900 at the time of the survey), with the main costs being attributed to pond construction (mean 32%) and land purchase (mean 30%), followed by storage (mean 12%) and facilities (mean 10%). The survey reported that only 4% of farms were built on land owned by the farmer.

According to Phan et al. (2009), the operating costs of tra catfish grow-out farms ranged from VND 84 million to 46.5 billion per farm per crop with a large proportion attributed to feed (mean 75%) and seed costs (mean 12%). The production cost per kg of fish ranged from VND 11 000 to 17 000 (14 200 ± 150, mean ± SE). The unit production cost when farm-made feed was used was VND 13 722 ± 1385 (range: 11 500–15 500), as opposed to VND 14 372 ± 1374 (range: 11 000–17 000) when commercial feeds were used. However, this difference was not statistically significant (\( P > 0.05 \)).

Bush et al. (2010) reported that from 2008 to 2010 catfish grow-out farmers experienced a 24% turnaround in their return on investment (from 11 to 13%) and suggested that this was indicative of the variability of the profits and also the cyclic nature of the returns. According to Bush et al. (2010), in the final cycle the farmers suffered an average cumulative net loss of US$ 1821 ha\(^{-1}\).

These authors also compared cumulative profits (from July 2008 to April 2010) of tra catfish farming versus other species farmed in the Mekong Delta. The results suggested that tra catfish nursing was the most profitable, enabling the farmers to make a cumulative total of approximately US$ 6500 ha\(^{-1}\) and grow-out resulted in a loss. However, all other farmed species resulted in a cumulative profit (Bush et al. 2010). This study, which was conducted over a short period of time, indicates the volatility of the sector; economic viability is impacted by small changes in the farm gate price.

De Silva (2011, in press) outlined the costs along the value chain. It is evident from Figures 11 and 12 that the profit margins at each link are very meagre, including that of the processors (also see Fig. 13). The latter, whose investments in the processing plants are very high, are barely able to remain viable through the selling and processing of offal, whereas the retailers appear to make proportionately significantly higher profits. However, it is important to point out that there have been significant improvements over the years in the processing yield. For example, if one assumes that all tra catfish produced is processed the yield from 2002 to 2010 has improved.

![Figure 10](image-url) Trends in the average farm gate price and export price of tra catfish. Avg., average. (– –) Avg. farmgate (US$ kg\(^{-1}\)); (– –) avg. export price (US$ kg\(^{-1}\)).
significantly, dropping from 5.40 to 1.77 kg, and averaging 1.69 kg (1.69 kg of fresh fish yields 1 kg of processed product) for the period 2005–2010. This marked improvement in processing yield would have contributed to the economic viability of the processing units.

From the foregoing facts it is evident that many business units within the tra catfish farming sector operate at very marginal economic levels. Bearing in mind that the great bulk of producers are small scale, a shift in farm gate price, particularly in the wake of the increasing costs of inputs, primarily feeds, often makes the practices almost economically unviable. However, the high production turnover enables these small-scale practices to remain viable. It is, therefore, imperative that to retain

Figure 11 A schematic representation of the value chain from producer to processor including the estimated costs at each stage of processing to produce 1 kg of frozen fillet. This diagram is based on a survey conducted by the authors of two major processors of tra catfish in August 2008. It is assumed that 3 kg of raw catfish is required to produce 1 kg of processed product. Avg., average.

Figure 12 A schematic representation of the observed cash flow in tra catfish farming value in the Mekong Delta, Vietnam (VND 17 500 = US$ 1.00) (from De Silva 2011). Note that the processing yield was calculated at 35–40% (i.e. nearly 2.8 kg of fresh fish is required to produce 1 kg of processed product).
economic viability of the tra catfish farming sector there needs to be more realistic price structures worked, such as a guaranteed price scheme at each link of the value chain, to prevent the occurrence of peak and ebb cycles, which appear to be common (Hong 2010; Nghe 2010).

**Product quality**

Public perceptions on the nutritional benefits of fish consumption have been boosted very significantly with the observation that it offers specific health benefits (e.g. Connor 2000; Ruxton et al. 2005), in particular the intake of highly unsaturated fatty acids (HUFA) of the omega 3 (n-3) series, 20:5n-3 (eicosapentaenoic acid, EPA) and 22:6n-3 (docosahexaenoic acid, DHA). What is often not taken into consideration is that in general freshwater fish species do not store significant quantities of n-3 HUFA, unlike their marine, carnivorous counterparts (Kanazawa et al. 1979; Henderson & Tocher 1987), and the likely reasons for these differences are well understood (Kanazawa et al. 1979). However, there are many nutritional benefits gained from the consumption of all fish species, such as a high proportion of easily digestible protein with all essential amino acids and an array of vitamins and micronutrients (De Silva & Anderson 1995). Tra catfish falls into the latter category. Moreover it has a flesh appearance and texture that is often compared to that of ‘white fish’, often suited to what is known as the ‘Western palate’ (Phan et al. 2009). What is important for the tra catfish sector is not to attempt to increase the n-3 fatty acid content of the flesh, which would raise the cost of production to exorbitant levels, but to maintain product quality and safety as it stands. Attempts to give tra catfish the same qualities as salmon (i.e. the same nutritionally favourable fatty acid profile) are not likely a realistic proposition, particularly from economic and resource use (e.g. fish oil use in feeds for tra catfish) points of view.

Orban et al. (2008) determined the flesh quality of tra catfish fillet samples from supermarkets in Italy. Apart from the fact that the level of protein in the fillets was comparable to that of other fish, the results showed that the lipids were characterised by low cholesterol levels (21–39 mg per 100 g), a high percentage of saturated fatty acids (41.1–47.8% of total fatty acids) and a low percentage of polyunsaturated fatty acids (12.5–18.8% of total fatty acids). The authors also reported that from a safety viewpoint only very low residues of mercury, organochlorine pesticides and polychlorinated biphenyls were detected.

The EU has developed a Rapid Alert System for Food and Feed to ensure food safety and quality from farm to fork (http://ec.europa.eu/food/food/rapidalert/index_en.htm). The system provides an alert if a food stuff, at the market or at the point of landing, does not meet the food quality standards specified by the EU, leading to a Rapid Alert Notification (RAN) being issued for withdrawal of it from the market place or, in the case of cross border transmission, rejection of the consignment.

The EU has been the main importer of tra catfish since 2005 and currently accounts for the import of 35–40% of all processed tra catfish from Vietnam (see Fig. 7). Perhaps, one of the most reliable criterions available for assessment of the quality of tra catfish exports is through the information available from this system. Accordingly, Figure 14 depicts the trends in total catfish imports to the EU and the number of RANs issued on such imports, as well as the categories (e.g. microbiological, veterinary drugs) under which such notifications are issued. However, neither the total tonnage nor other details relevant (e.g. supplier) to any one RAN is publicly available.

However, a reasonable extrapolation can be made by relating the total imports and the number of RANs issued, irrespective of the category, when it is clearly seen that RANs issued per 10 000 t of catfish imports to the EU have declined most markedly (Fig. 14). Admittedly, in 2009 and 2010 there was an upsurge in RANs, the bulk of which resulted from microbiological causes. Equally...
important to note is that overall there had been a very significant decline in RANs from veterinary drugs, indicative of the fact that the use of restricted/banned chemicals in tra catfish farming has declined and the producers are complying to a very high degree to the regulatory measures. The RANs on microbiological grounds could emerge from contamination during the processing, storage and transportation stages in the value chain, some of which could be beyond the control of the exporting countries. Some of the causes (e.g. *Listeria monocytogenes*) suggest that criteria applicable for ready-to-eat (RTE) foods are applied to tra catfish fillets, which are generally consumed after cooking.

In an era where vigilance and regulatory measures on food quality and safety are becoming paramount, backed up by ever increasing improvements in detection and analytical techniques, significant reductions in RANs of the EU are indicative of the compliance of the tra catfish sector to food safety and food quality regulations. The aforesaid evidence disputes the derogatory publicity on the Web (see Use of the World Wide Web to discredit tra catfish) on the food quality and safety of tra catfish. Over the years the numbers of processors and exporters of tra catfish have increased significantly (see Fig. 8) and it is in this context that authorities perhaps need to tighten up vigilance at the processing, storage and transportation links of the value chain to further minimize the RANs on catfish imports, a hallmark of safety and quality.

**Environmental impacts**

The Mekong River (known in Vietnamese as the Cuu Long River), with a mean discharge volume of 15 000 m$^3$ s$^{-1}$ (the 10th highest in the world), traverses 4880 km through six countries (van Zalinge et al. 2004), and divides into seven major branches when it enters the delta, approximately 170 km from the South China Sea. The lower Mekong, with a basin area of 612 510 km$^2$, runs through four riparian countries (Cambodia, Laos PDR, Thailand and Vietnam) and is home to nearly 60 million people, the majority of whose livelihoods are dependent, directly and/or indirectly, on river resources (MRC 2010). The main stream of the Mekong is dammed in the Chinese territory, but not elsewhere, although some of the major tributaries in the Lower Mekong are dammed (MRC 2010). In view of its importance for navigation, power generation, fish diversity and food fish resources (Coates 2002; De Silva et al. 2007; Valbo-Jorgensen et al. 2008; Hortle 2009), the environmental aspects from a variety of angles of the Mekong River have been the subject of many studies (Li & He 2008; Varis et al. 2008; Walling 2008).

Given that development of the tra catfish farming sector is comparatively recent, the number of studies conducted on the environmental impacts of the sector however, is relatively limited. Bosma et al. (2009) conducted an environmental impact assessment of the sector using a seven step process and stakeholder interactions, involving inputs and outputs of 28 grow-out farms and four hatcheries/nurseries. According to this study, feed production, which largely takes place outside of Vietnam, dominated the environmental impact of the tra catfish farming sector. However, the authors noted that grow-out farming contributed to eutrophication and ecotoxicity of the Mekong River, the contribution of farming to these phenomena depending heavily on whether or not pond sludge was discharged into the river.

Bosma et al. (2009) also observed that as only approximately 2% of Mekong River water passes through catfish rearing ponds the impacts on Mekong River water quality were relatively limited because sedimentation, mineralization and infiltration occur in the ponds and because the river’s natural nutrient content is high. The authors pointed out that in a worst-case scenario tra catfish farming contributed 2.4% of N and 3.7% P to the river contents, with the possibility of these levels being further reduced by approximately 90% to <0.05% by proper sediment management. The authors, based on these observations, made a series of recommendations to policy makers, feed producers, tra catfish farmers and researchers.

De Silva et al. (2010) analysed a number of commercial feeds and farm-made feeds used in tra catfish farms, the latter made on site using locally procured raw materials, a relatively common practice in the sector. These authors used a mass-balance method to estimate the nutrient (primarily N and P) discharge levels. The results showed that N discharge levels were similar for commercial feeds (median 46.0 kg per tonne fish) and farm-made feeds (median 46.8 kg per tonne fish); P discharge levels for commercial feeds (median 14.4 kg per tonne fish) were considerably lower than for farm-made feeds (median 26.6 kg per tonne fish). Based on the median nutrient discharge levels for commercial feeds, striped catfish production in the Mekong Delta discharged 31 602 t N and 9893 t P, and 50 364 t N and 15 766 t P in 2007 and 2008, respectively. The authors suggested (as did Bosma et al. 2009) that the amount of nutrients returned directly to the river may be substantially less than this as a large proportion of the water used for catfish farming as well as the sludge is diverted to other agricultural farming systems. It was also pointed out that striped catfish farming in the Mekong Delta compared favourably with other cultured species, irrespective of the type of feed used, when the total amounts of N and P discharged from a tonne of production were estimated.
Anh et al. (2010) evaluated the discharges from processing of the catfish farming sector and demonstrated that in the processing of 1 tonne of frozen fillets, the main export commodity from the sector, 740 kg of Biological Oxygen Demand (BOD), 1020 kg of Chemical Oxygen Demand (COD), 2050 kg Total Suspended Solids (TSS), 106 kg of N and 27 kg of P were produced. Of these, the study estimated that effluents from grow-out ponds contributed 60–90% and waste from processing plants contributed 3–27%. In contrast, the overall emissions from tra catfish farming contributed <1% of the TSS, N and P in the Mekong Delta as a whole; this level of discharge into the environment is miniscule for a sector that produces over one million tonnes and generates a revenue in excess of US$ 1 billion. Moreover, the authors proceeded to suggest ways and means of further reducing the impact of effluent on the environment.

An often expressed concern in the media and in critiques of tra catfish farming is the liberal use of water from the river, uncontrolled discharge of pond effluent into the river and the lack of a strategy for the disposal of pond sludge. We have shown that the nutrient loads in the effluents are not that excessive for a farming activity of this magnitude and that the amount discharged, in particular the amount of N and P per kg of produce, is comparable to other cultured commodities (De Silva et al. 2010). Equally, it has been pointed out that in accordance with the Better Management Practices (BMPs), which are being embraced by small-scale striped catfish farmers (NACA 2011), either sedimentation/reservoir ponds and/or strategies for the disposal of accumulated pond sludge need to be developed and adopted, which will further enhance product quality and environmental well-being.

With regard to the above, Phung et al. (2009) reported that in the dry season of 2007 yields in rice paddies receiving waste from tra catfish ponds increased by 1 t ha⁻¹. Phung et al. (2009) tested the effectiveness of three doses of solid waste (1, 2 and 3 t ha⁻¹) in combination with with one-third or two-thirds of the recommended inorganic fertiliser input rates (60N:17P:24K in kg ha⁻¹), and found that there were no significant differences in the yields under the different treatments. Comparable results were obtained when liquid waste (effluent) from ponds was tested. The authors suggested that it may be possible to recycle sludge and/or liquid effluent as a fertiliser input to rice paddies, bringing about significant savings to rice farmers and of course with overall environmental benefits to both rice and fish farming in the Mekong Delta.

Overall, the environmental impacts of tra catfish farming are well within the acceptable levels for a comparative food production system. Further improvements to reduce the impacts of the tra catfish farming sector are in the offering, and indeed generating synergies by combination with the rice-farming sector in the use of pond sludge. Possibly this is a major strategy that needs to be developed through appropriate policy developments for the sector. A concerted effort to develop ways and means of using catfish pond sludge in rice farming as a business proposition, benefiting both sectors, environmentally and economically, will be most appropriate. Such a development will set an example for combining and drawing synergies between primary production sectors in an effective manner. All this, however, does not and should not lead to complacency, and all endeavours should be made to further minimise environmental impacts leading to long-term sustainability of this most socioeconomically important sector. After all, no farming systems, either on land or in the water, can be expected to have zero impact on the environment. However, it is incumbent on all to minimise such impacts and this will ensure the sustainability of the farming system(s).

Aquaculture developments also have to ensure that minimal impacts occur to biodiversity, irrespective of whether the cultured species is indigenous to a locality/watershed or alien. Often aquatic biodiversity loss is attributed to aquaculture and the use of alien species in aquaculture, although in many instances these propositions are not backed by explicit scientific evidence (see De Silva et al. 2006, 2009). In contrast, the aquaculture of an indigenous species could bring about indirect genetic effects on its wild counterparts through the dilution of genetic diversity (Waples 1991) and/or hybridisation with related species. Such impacts have been reported in the Thai silver barb and walking catfish in Asia (Kamront 1996; Na-Nakorn 2004). However, to date, available evidence suggests that comparable impacts on the genetic diversity of wild stocks of tra catfish and related species have not resulted from hatchery-reared stocks (Ha et al. 2009). However, this is no reason for complacency, and continued monitoring of wild and hatchery stocks of tra catfish in the Delta is warranted in association with long-term broodstock management strategies for the latter (Nguyen 2009).

An important development in the tra catfish sector is waste recycling, which unfortunately has rarely been acknowledged by critiques and environmental groups. The processing sector, for example, in the period 2005–2010 processed 4 783 363 tonnes of tra catfish that yielded 2 807 671 tonnes of exportable produce (VASEP 2009, 2010), which resulted in waste amounting to 1 981 692 tonnes. However, this waste was not released into the environment or used as fertilizer, but re-processed to extract oil and then processed into a meal for use in the animal husbandry sector. This waste generates significant income for the processors, perhaps
increasing their economic viability, and most importantly the environmental gains are significant. This is an area that warrants further detailed study from both an economic and environmental perspective, and the results could be used by authorities to popularise catfish farming from an environmental viewpoint.

**Improvements to management practices**

Figures 3, 5 and 6 depict the trends in production, export volume and value of the tra catfish farming sector over the years, trends in the pond area in tra catfish farming and the production per unit area, and trends in the export volume of tra catfish and the number of countries exported to, respectively, and provide a snap shot of the development of the tra catfish sector over the past decade. It is evident from these figures that there has been a gradual upsurge in production and the extent of imports of processed fish, but more importantly these have gone hand-in-hand with an increase in production per unit area. Equally, it is apparent that there has been a decrease in the number of RANs issued on tra catfish imports to the EU, which is indicative of improvements to the quality of the produce.

Underlying all such developments and improvements are likely to be improvements in the management of the sector as a whole. In view of the very high intensity of tra catfish farming practices and the rather free use of water from the common resources, the two Mekong River branches and associated channels, and the increasing pressures from markets for compliance to standards and certification procedures, there is still much room for improvement in farming practices. The latter aspects will be dealt with later in detail in this review.

The tra catfish farming sector, although essentially an export-oriented farming sector (see Fig. 5), is still by and large a small-scale farming sector, with individual practices farmer owned/leased, operated and managed. Small-scale farming systems almost always face the challenge of complying to standards and certification procedures, primarily because of the cost involved in obtaining such certifications; these costs are barely affordable as these farms operate at relatively marginal economic levels.

Studies have shown that the development and adoption of BMPs for small-scale shrimp farming practices in Andhra Pradesh, India, and the organization of the farming communities into clusters have been extremely effective (Umesh et al. 2010). In such cases, yields have increased, disease occurrence has been reduced, profitability has improved and most of all groups have been able to access markets that were not possible to access as individuals. Furthermore, the adoption of BMPs and the cluster approach has generated synergies, a greater social harmony and improved the bargaining power as a community, including cluster certification.

Better Management Practices for the catfish sector in the Mekong Delta have been developed (NACA 2011; http://library.enaca.org/inland/catfishbmps/catfish.bmp_v2.pdf) and have been adopted by groups of farmers and the organization of clusters is in progress. These developments are likely to have profound improvements on the management of farming practices, as in India, leading to cluster certification. Most importantly, clusters provide the opportunity to develop water intake and discharge calendars, thereby bringing a rationalization of water use and impacting positively on the total discharge of nutrients into the river and reducing potential disease occurrence through contamination.

Better Management Practices are not standards, but rather a pragmatic path to improved management. The BMPs incorporate most aspects of day-to-day management, including monitoring of water quality, aspects of feed management, recording of mortalities, strict prohibition of banned chemicals, norms on effluent discharge, all of which are facets of standards and certification schemes. The adoption of BMPs, which are constantly being improved, is sufficient to meet most, if not all, standards that are currently in place.

**Trade-related issues and obstacles confronting the sector**

With tra catfish being essentially and almost totally an export commodity, the sector has had to confront and continues to confront many trade-related issues, directly and/or indirectly. It is to the credit of the sector and the authorities involved that these issues have not impacted on the production and processing sectors, which essentially provide livelihood means to almost 180 000 rural poor. The literature on trade and market-related issues on tra catfish is voluminous and no attempt will be made here to review it all, but rather we will highlight those issues that are considered to have had the most impacts on the sector.

It is generally accepted that globalization benefits growth, encourages technology transfer and alleviates poverty, hunger and malnutrition. Globalization in trade functions through various negotiation rounds of the World Trade Organization (WTO) and its predecessor the General Agreement on Tariffs and Trade (GATT). Consequently, tariff barriers have been reduced worldwide, encouraging free trade. However, antidumping measures are being increasingly used by nations as a means of protecting their own produce against competition from imports (Zanardi 2004). Trade between nations has also been augmented through organizations.
such as the Asia–Pacific Economic Cooperation (APEC), by reducing tariffs and non-tariff barriers among its member nations.

**US trade restrictions**

‘Dumping’ is a commonly used term with respect to many traded commodities. Dumping refers to when a commodity is exported at a lower price than its production cost. Related to this is the issue of when the producing/exporting nation is a ‘non-market economy’, in that the labour costs incurred are not comparable with those of a market economy (e.g. labour costs in the USA versus those in Vietnam). These are some of the factors that lead to trade restrictions and an increase in the tariff on tra catfish imports to the USA.

Soon after Vietnam gained membership to APEC tra catfish exports to the USA soared to unprecedented levels; for example, from 280 000 kg in 1998 to more than 7.7 million kg in 2001 (Sengupta 2003); this marked increase coincided with the dropping of raw seafood tariffs. This upsurge in tra catfish exports from Vietnam caused an uproar in the catfish farming sector in the USA, which farms a different species, the channel catfish, *Ictalurus punctatus*. The result of this uproar was that the US Congress passed a law in November 2002 restricting the use of the word ‘catfish’; catfish labelling was only allowed to be used for the family Ictaluridae (Narog 2003), and concurrently the USA sought a renegotiation of the 2001 Bilateral Trade Agreement (BTA) between the USA and Vietnam, with a view to restricting the quantity exported (Kinnucan 2003). All of this resulted in a sharp decline in catfish exports to the USA until approximately 2005 (Nguyen 2010). In essence this confrontation was the first ‘catfish trade war’. These actions led to lengthy negotiations, and during this time the Government of Vietnam had to ensure that the growing catfish farming in Vietnam was not adversely impacted, so it took steps to popularize tra catfish sales in other countries and make it a genuine ‘internationally’ traded commodity.

Nguyen (2010) traced these developments and applied econometric models for price impact assessment of antidumping measures and labelling laws on Vietnamese striped catfish. The basic conclusions from Nguyen’s (2010) study were that: (i) an antidumping tariff raised the US domestic price of processed catfish and lowered the Vietnamese export price; (ii) the fall in the price of Vietnamese catfish caused by the US tariff raised market demand outside the USA and consequently boosted the Vietnamese export volume of catfish; (iii) although the BTA benefited US consumers the antidumping measures were not favourable to the US consumers or to US farmers; and (iv) the labelling law in reality harmed the US catfish industry and helped the Vietnam catfish industry to forge ahead.

Interestingly, Duval-Diop and Grimes (2005) compared catfish production in the Mekong and Mississippi Deltas and used the globalization concept to illustrate how these very geographically and culturally different entities have been brought to competition and how this competition is mediated. The authors highlighted how a comparable commitment to an economic development strategy, such as catfish production, a desire to gain access to wealthy consumers who are willing to purchase this high-value food item and processing and transportation technologies that allow this perishable product to be made more ‘durable’ and to be shipped great distances bring these two deltas together. The study also illustrated the heterogeneous outcomes of globalizations as these deltas are brought into a relationship that, in some ways, is closer than their absolute distance may indicate. The authors also suggested that ‘backlash’ forces, such as non-tariff trade barriers, nationalism and a still-powerful state (as both a regulator and consumer), characterize these globalizations. These authors also noted that overall the Vietnamese tra catfish gained in the episode and provided the sector with the opportunity to explore a wider international market.

Given this background, even today the US antidumping tariff on Vietnamese catfish exports to the USA remains valid. The USA wanted to raise the tariff to 130% in 2009. Overall, starting from January 2003, antidumping tariffs ranged from 44.66 to 63.88%, depending on the individual company (Intrafish 2003), and essentially these tariff increases (USITC 2002) are an indirect discouragement that is in existence to curtail tra catfish imports to the US.

**Use of the World Wide Web and other media to discredit tra catfish farming**

It is a well known and accepted fact that the World Wide Web provides a vehicle for any consumer to be informed of a variety of matters, including food quality. It is also a fact that the medium can be used, relatively effectively, to discredit certain products, gaining access to millions of users with a variety of information, discrediting and/or crediting. In either case such information creates doubt in the mind of potential consumers.

Ironically, the information provided on the Web does not need to be authenticated or be scientifically and/or factually correct. It is not surprising that tra catfish, which is being traded throughout the globe at a very reasonable price to the consumer, but not so to the producer, is often targeted by individuals (e.g. http://www.betterbods.co.nz/basafish.htm; http://4udiary.blogspot.com/2009/05/be-careful-when-you-buy-fish-and-chips.html; http://
groups.yahoo.com/group/dhinit2007/message/43; http://ummisal.multiply.com/journal/item/58/Dory_Fish......Sutchi_or_Pangas) or groups with many derogatory remarks on, for example, culture practices and its unsuitability for consumption.

Admittedly, the Web is available for all global citizens to access information. The final decision regarding the purchase of a product, however, is at the discretion of the person who seeks the information. Nevertheless, the continuous bombardment of information discrediting a product, including its mode of production, could indirectly bias potential customers. It is incumbent on the Vietnamese authorities, who are responsible for developing policies and the well-being of the sector, to ensure that such negative publicity is disputed, using the same media sources. Indeed it is incumbent on these authorities, as well as those organizations that are mandated to facilitate sustainable development of aquaculture for the provision of livelihoods among rural poor and food security, to explore the possibility of challenging erroneous publications on the industry through available international legal channels.

Apart from the use of the Web, there have been reports or rather misreports of the tra catfish farming sector in other media. A most notable and recent example is a program entitled 'The Pangasius Lie', which was aired on a German TV channel on 14/03/2011 (Urich 2011). It has been suggested that this program was very one-sided and biased and led one very experienced journalist to comment that it was one of the worst examples of ‘killer journalism’ that he has ever experienced. According to Urich (2011) many others have commented on this program and ‘every ethical code of true and honest research has been violated in this [program] and the target is clear – kill the industry, slander the fish, do not care about the truth, but smash them [industry workers] where you find them’.

Most importantly, this program is supposed to have been made in conjunction with the World Wildlife Fund (WWF). The authenticity and lack of scientific proof of the statements in the program have been questioned and Urich (2011) concluded ‘it is not just Neubacher who believes that the seafood industry should not get into bed with the WWF’.

Certification-related issues

Background

The realisation that food quality and standards must be upheld led to the formation of many global organizations that were assigned tasks to develop guidelines and strategies for achieving these basic purposes. One such organization was The Codex Alimentarius Commission, created in 1963 by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO); the aim of the Codex Alimentarius Commission was to develop food standards, guidelines and related texts, such as codes of practice, under the Joint FAO/WHO Food Standards Programme. The main purposes of this programme were to protect the health of consumers and ensure fair trade practices in the food trade, and promote the coordination of all food standards work undertaken by international governmental and non-governmental organizations (http://www.codexalimentarius.net/web/index_en.jsp).

Interestingly, in the 1960s, there was the development of the Hazard Analysis Critical Control Point (HACCP), initially conceived by the US National Aeronautics and Space Administration (NASA), to ensure that food destined for space travel was of the highest quality. Since then HACCP has been recognized internationally as a logical tool for adapting traditional inspection methods to a modern, science-based, food safety system. HACCP has expanded into all realms of the food industry, into meat, poultry, seafood and dairy, and has spread now from the farm to the fork, and is based on seven basic principles that have become HACCP standards. The seven HACCP principles are included in the international standard ISO 22000 FSMS 2005. This standard is a complete food safety and quality management system that incorporates the elements of prerequisite programmes, HACCP and the quality management system, which together form an organization’s Total Quality Management system (http://en.wikipedia.org/wiki/Hazard_Analysis_and_Critical_Control_Points#History).

Over the past two decades with liberalisation of trade there has been a global push to take appropriate steps to ensure that not only food quality and safety are achieved with respect to internationally traded food commodities, but also that the production systems adhere/comply to accepted norms and are socially responsible. These norms also ensure, for example, that farming systems have minimal environmental impact and that the production systems are sustainable. In addition, markets increasingly recognize that some form of certification is a way of assuring buyers, retailers and consumers that fisheries products are safe to consume and originate from aquaculture farms or capture fisheries adopting responsible management practices. It is in this context that certification procedures came into being, and the aquaculture sector had to follow suit.

Accordingly, steps have been taken to introduce globally accepted certification guidelines such as, for example, ecolabelling of fish and fishery products (Deere 1999; FAO 2005), and certification guidelines for aquaculture are in the final stages of adoption (http://www.enaca.org/modules/certificationprojects/index.php).
Needless to say that as public and institutional demand for certification of aquaculture products began to develop there was a mushrooming of third party private certification schemes (Roheim 2009), some of which were driven by profit motives. Such mushrooming has lead to confusion among producers and a general lack of transparency in the systems (FAO 2010), and in some quarters these schemes are referred to as a ‘jungle of confusion’. Harmonized certification guidelines that are pragmatic, transparent and accepted by governments will bring about an end to this confusion (FAO 2010), so that governments in conjunction with producers can move forward. A summary of some of the schemes for aquaculture are available on a dedicated web page of the FAO and the Network of Aquaculture Centres in Asia–Pacific (NACA); this summary has been posted for the purposes of disseminating information on the Development of a Global Certification Scheme for Aquaculture and related aspects (http://www.enaca.org/search.php?query=Certification&action=results).

It is important to note that certification guidelines are drawn up using a consensus-based process involving, for example, almost all members of the FAO through an extensive process of consultations that involves as many stakeholders as humanly possible. In contrast, an industry sector may proceed to develop certification standards on a particular aspect of the farming, but does so through the involvement of sector stakeholders (e.g. for salmon farming in Chile; Fundacion Chile 2003).

Certification and standards

Needless to say, in most quarters there is a lack of understanding with regard to certification and the difference between certification and standards. Standards are independent of certification and are mostly a set of criteria developed by private and/or non-government organizations (NGOs) and are often commodity and trade driven (also see Belton et al. 2011). Moreover, the ‘developers/owners’ of standards are linked to major trading houses and will insist that the said standards be met if the producer is to access that particular market. Standards can be both mandatory and voluntary. Mandatory standards are set by national authorities and international standard setting bodies (e.g. Codex, World Organization for Animal Health (OIE)). Third party private certification programs make use of mandatory standards and in addition use voluntary standards. The question has often arisen about whether the standards developed for a commodity/farming system are real, practical and pragmatic. Serious concerns have been raised, for example, on the development of farm certification standards by the WWF for tilapia, a major cultured species in the tropics, providing many livelihood opportunities and contributing to food security. Belton et al. (2009), based on a study assessing the sustainability of tilapia farming systems in Central Thailand, criticized the ‘tilapia aquaculture dialogue’ of the WWF and suggested that new approaches are required if sustainable aquaculture is to be meaningfully understood and implemented.

Belton et al. (2010c) attempted to demonstrate that the draft certification standards subsequently developed fail to adequately integrate critical factors governing the relative sustainability of tilapia production and thereby miss more significant issues related to resource-use efficiency and the appropriation of ecosystem space and services. Belton et al. (2010c) raised the possibility that if these certification standards are adopted it will lead to the promotion of intensive systems of tilapia production that are far less ecologically benign than existing widely practiced semi-intensive alternatives.

What is apparent is that certification standards developed independently by many organizations are less than pragmatic and often commercially driven. As previously stated, however, in a globalized market economy, a balance has to be struck with the primary objective being to safeguard the producers’ livelihoods, particularly, the small-scale farmers, which constitute the backbone of the aquaculture sector, while at the same time ensuring food quality and safety as well as environmental integrity.

Certifications and standards in relation to the tra catfish sector

It is to be expected that many independent groups would embrace certification and standard development schemes for the tra catfish sector in view of its international importance, the volume of produce and the financial strength of the sector. It is in this regard that the WWF initiated a dialogue on developing certification standards for tra catfish farming, in the same vein as that done for tilapia farming, which was completed in 2010 (WWF 2010).

Belton et al. (2011) reviewed the application of standards for catfish farming in Vietnam and Bangladesh. In this analysis the authors suggested that certification is an increasingly pervasive form of market governance, through which retailers and NGOs tend to exert control over producers with a view to securing commercial and institutional interests. According to these authors there are six different standards of certification operating in Vietnam for the tra catfish sector, none, however, has been widely implemented as yet. The study also compared the main criteria used by each of these standards, and pointed out that some of these criteria are not pragmatic and do not take into consideration existing practices. Most importantly, the analysis concluded that proliferation of these standards could marginalize the very
small-scale farmers who might have to opt for other livelihoods because of an inability to comply, and also suggested that overall compliance to standards has not necessarily brought direct economic benefits to the producers, apart from ensuring market access where applicable.

Currently in An Giang and Can Tho provinces, for example, 526 ha of tra catfish farms out of a total of 5400 ha have been certified (N. T. Phuong, January 2011, pers. comm.) by Global Gap and Safe Quality Food (SQF 1000).

Interestingly, and for reasons unknown and obscure to many, the WWF also commissioned a report under the ‘The Common Aquaculture Methodology’ of the WWF (WWF et al. 2010). In this assessment of tra catfish, based on rather meagre observations and somewhat misinterpreted and/or interpreted out of context findings of three peer-reviewed publications on catfish, tra catfish was categorized under the ‘Red List’ of the WWF: a matter of serious concern to all stakeholders, including the Government of Vietnam, from a socioeconomic viewpoint. Consumer backlash resulting from such a ranking has the potential to impact on thousands of livelihoods and financially and as well as broader economic concerns.

As one would expect this triggered an immediate reaction from the Government of Vietnam, as it did with a comparable situation (i.e. the trade embargo on catfish), On learning of the listing (7 November 2010) of tra catfish on the Red List in the WWF handbook ‘A guide to seafood consumption’, the Government of Vietnam in conjunction with the Vietnam Association of Seafood Exporters and Producers (VASEP) called for an immediate dialogue with the WWF and called on the WWF to show how this decision was arrived at (http://www.agroviet.gov.vn/en/Pages/news_detail.aspx?NewsId=591&Page=1).


WWF is a world renowned brand name, extremely well known to the world at large and supported by both public and private donations. The world has acknowledged its many contributions on a wide range of issues of global importance, such as for example from conservation of threatened/endangered animals to adoption of “greener” farming strategies etc., etc. The world community, however, typically views WWF as a single entity with one consistent voice and not as separate operational units in different regions. In such a context one would expect uniformity in its actions over an issue, whether it be conserving a wild stock of animals or evolving a set of standards for a farmed product. The public expects that such an examination of an issue that is being addressed should take into account all related aspects, including provision of food and food security, and social aspects such as maintaining livelihoods – particularly for the poor and the impoverished – and not be biased in interpretation. The lack of such concerns in the above regard in respect of aquaculture produce, for example tilapia farming, as adopted by the WWF, was highlighted by Belton et al. (2010c), and it appears that this thinking continues to grow further around those matters raised in this review in respect of catfish farming in the Mekong Delta, Vietnam; in our view it is not the credibility of the catfish farming sector which is really at stake here but that of the WWF’s adoption of double standards.

Meeting the certification and standards

As previously shown, most tra catfish sector producers are small scale, selling to the processing factories on an independent or contractual basis. The processors though making a minimal financial gain from 1 kg of processed product (see Figs 11,12), are well within the financial capability of paying the designated fee for certification of the final product. In contrast, in the case of the small-scale farmers, certification payments, which are gradually becoming compulsory, may be prohibitive, unless group certification is obtained.

In this regard, NACA has attempted to promote the concept of group/cluster certification so that small-scale farmers can participate in market-driven third party certification programs of their choice and thus are not left out of the race. Sharing the food production guidelines with growers, food producers and retailers – specifying how food is grown and what has been used to produce it – is an important contribution to the harmonization of trade, enabling clear and transparent processes. Thus, certification is seen as a tool of communication between the primary producer and the end consumer, enabling primary producer economic freedom with social responsibility. ‘Certification is a procedure by which a certification body gives written or equivalent assurance that a product, process or service conforms to specified requirements and is carried out by competent and accredited body’ (Adopted from IFOAM). Keeping in mind the fact that nearly 90% of the aqua farmers are small-scale operators and that certification for individual farmers is not only prohibitively expensive, but also impractical, grouping small farmers that share common natural resources becomes imperative to extend coverage to all small-scale farmers in a cost-effective manner.

Group certification refers to ‘Certification of the Group comprising of small scale farmers of a given locality sharing
the common resources and employing a common technology to promote sustainable aquaculture under an entity (Aqua Society and or equivalent) that manages and documents a clear and transparent Internal Quality Assurance System’ (NACA 2011). Group certification is intended for groups of (small-scale) farmers affiliated and operated under a legalized entity (e.g. Aqua Society) and the certificate issued will be in the name of the Aqua Society and/or equivalent. Compliance to set standards by every individual member and collectively (Aqua Society) is mandatory for Group Certification. Responsibility (both at an individual and collective level), unity and compatibility of members are the essence of group certification and call for efficient coordination among the farmers.

It is in this regard that the certification of Aqua Societies (or equivalent), which led to cluster certification being developed for small-scale shrimp farmers in India through a collaborative effort between the Marine Products Export Development Authority (India) and the Network of Aquaculture Centres in Asia–Pacific (NACA), is of relevance (Umesh et al. 2009; also see http://www.enaca.org/modules/certificationprojects/index.php). Following the success of the Indian experience, for the tra catfish sector, which also comprises a large proportion of small-scale producers, to meet the demands of globalization it would be most appropriate for it to also adopt such a strategy.

The tumultuous path to success

It has been pointed out that aquaculture, despite being a millennia old tradition, is literally ‘the new kid on the block’ when it comes to modern day primary production sectors (De Silva & Davy 2010). Consequent to this new emergence as a significant contributor to food fish production and providing food security to many millions of rural households, scrutiny of the sector has perhaps been unprecedented when compared with other food production sectors. De Silva and Davy (2010) pointed out that this is to be expected with modern aspirations in relation to all developments further driven by globalization. Needless to say that tra catfish farming is not spared either in this regard.

In contrast, tra catfish farming has had a very tumultuous path to success that has not been experienced by any other aquaculture sector thus far. In the primary production sector, perhaps the best criteria for measuring success are the level of production, the number of livelihoods the sector provides, the financial and economic gains of the sector and whether it delivers benefits to society with minimal impacts on the environment. With respect to all of the above criteria, the tra catfish farming sector is considered to have performed admirably well. In general, the failure and/or the thorniest issue to success is disease and a concurrent collapse of the sector. In this regard the example of the virtual collapse of culture of the black tiger shrimp (Penaeus monodon) in Asia is foremost; the preferred solution adopted by many countries to save the sector and the associated livelihoods was to shift to the culture of exotic white-legged shrimp (Litopenaeus vannamei).

The tra catfish farming sector, in contrast, at least to date, has not been impacted by disease pandemics, nor has the sector witnessed any boom and bust cycles. The factors that this sector has had to confront are essentially trade-related and pressures from environmental groups. The latter has primarily impacted indirectly through attempted persuasion/influence to avoid consumption of tra catfish. Some lobby groups continue to assault the sector; however, none of the material used has any scientific backing. To date, the Government of Vietnam has dealt with any trade-related issues, and the government has ensured that the producers and processors have not been impacted adversely, except for some short-term shocks, and that the sector continues to retain its growth and development momentum. Relevant stakeholders should consider any environmental concerns carefully and develop strategies that will sustain the industry in the long run with minimal environmental perturbations. The adoption of BMPs, cluster management approaches and compliance to responsible farming practices would help to deter future problems.

Having said that, it is also apparent that the great bulk of producers who tend to be small scale are continuing their practices at the brink of economic viability in view of the lower farm gate prices, while the cost of inputs, primarily feed, tends to escalate (Bush et al. 2010). This has lead to small-scale farmers adopting a ‘wait and see attitude’ in which they suspend tra farming until the farm gate prices make it economically viable.

Authorities have now realised that ensuring an economically viable farm gate price is a key to sustaining the production side of the sector, and accordingly Vietnamese authorities have imposed a minimum farm gate price of VND 19 500, and for exports the floor price will be US$ 3 per kilogram for white-flesh catfish and US$ 2.05 for red flesh. It has also been reported (December 2010) that the purchase price of catfish is now VND 23 000–23 500 compared with VND 18 000 in October 2010, and the average export price is US$ 3 (Vietnam Business News 2010).

A look into the future

Aquaculture is becoming an increasingly important food production sector, currently accounting for nearly 50% of
Aquaculture is very different from other animal food production sectors primarily in the diversity of the taxa that are farmed. For example, in 1950 only 72 species belonging to 32 families were farmed; this had increased to 336 species from 115 families by 2006 (FAO 2006; Bartley et al. 2009). However, for only a handful of these species does the annual production exceed one million tonnes (nine finfish; five aquatic plants; three molluscs; FAO 2010). Tra catfish farming is one of these and its production ranks eighth among all farmed finfish species. More importantly it has achieved this level within a span of 10 years, starting from 2001 when reported production was only 114 000 tonnes.

Bush et al. (2010) suggested that the diversification of international markets led to the rapid growth of the tra catfish farming sector in the Mekong Delta, this rapid development was somewhat unplanned, uncoordinated and largely unregulated. However, despite the fact that most catfish farming practices are small scale (Phan et al. 2009; Bush et al. 2010), there appears to be a general belief that for the long-term sustainability and economic survival of this sector it will have to make a shift towards large-scale farming practices; the old adage of the notion of economies of scale being applied to tra catfish farming and the question being asked is whether there is a business case for small holders in the sector (Bush et al. 2010). This notion has also led to policy decrees to suggest that future developments should be for farms over 30 ha.

The above raises the question: why should tra catfish farming be different from other primary production sectors in Asia, which have been extremely successful over a long period of time, providing livelihoods and food security to millions of people, in particular rural communities. For example, in China, the largest rice producer in the world (182.042 x 10^6 t in 2006; 29% of global production), the average farm size is only 0.93 ha and in India, the largest dairy producer does so with 210 x 10^6 cows and buffaloes owned by 70 million households (RAP 2007). There have been many studies on farm size and the relationship between farm size and productivity, with respect to various crops (e.g. Fan & Chan-Kang 2005; Eastwood et al. 2004).

Even in terms of aquaculture, it has been clearly demonstrated that in Asia, the backbone of global aquaculture, the great majority of practices are small scale (De Silva 2011, in press). It has also been demonstrated that when shrimp farming (black tiger shrimp, Penaeus monodon in particular) was impacted adversely by the viral diseases and the decision was taken to replace this species with the exotic white legged shrimp. Most practices that survived the calamities and were able to adopt new species were small scale, and this success was attributed to the resilience and adaptability of small-scale farmers to calamities and changes (Kongkeo 1997; Kongkeo & Davy 2010).

Admittedly the tra catfish farming sector is very different, in that it is geared to an export economy and therefore the processing sector is a pivotal link in the value chain. Investments in the processing sector are highly capital intensive. Although many processors operate their own production facilities they still depend heavily on outside producers for the raw material. These outside producers are mainly small-scale farmers (Phan et al. 2009), whose economic viability is very much dependent on the prevailing farm gate prices. As the profit margins of small-scale farmers are rather low, and a small drop in farm gate price could make their practices economically unviable, the trauma catfish farming sector is almost always in a state of flux. It is in this context that Bush et al. (2010) demonstrated that farmers tend to stop farming catfish and that there is a greater degree of abandoning of the practices among small-scale farmers (Fig. 15). Even in this analysis it is evident that the average farm size, for all categories, is rather small and will fall well within the realm of small-scale farming (farmer owned/leased, operated and managed). The updated numbers for 2009 (Fig. 15) indicate a relatively high discrepancy with previous years as reported by Bush et al. (2010), and the present authors are of the view that the number of farms is over estimated. However, despite this discrepancy, the trend for very small farms to curtail operations is apparent. In the same vein when farm gate prices increase to a level to attain economic viability these small-scale farmers can easily recommence their practices.

As such the solution to the problem is not to discourage small-scale farming of tra catfish, but rather to ensure that farm gate prices are maintained at a realistic level, thereby ensuring that this export-oriented primary

![Figure 15](image.png)

**Figure 15** Changes in the proportion of practicing farms of different size classes over the period 2006–2008. The absolute number of farms in each size category is indicated within the bars. Years 2006–2008 are redrawn from Bush et al. (2010); 2009 data came from the An Giang Provincial Administration. (□) >1 ha; (■) 0.5–1 ha; (□) <0.5 ha.
production sector is sustained, and that thousands of livelihood opportunities are not lost. Importers, retailers and consumers have this moral responsibility, while enjoying the benefits of affordable fish.

One obvious aspect that has to be addressed with respect to tra catfish farming is the potential impact of climate change, which unfortunately has not been an area that has received any attention from policy makers. The importance of seeking adaptive changes to climate change impacts is paramount to this farming sector, particularly in view of the predicted sea level rise and consequent saline water intrusion well into the lower reaches of the Mekong River in the foreseeable future. This fact is likely to be further exacerbated by reduced river flow and changes in rainfall patterns (White 2002; Khang et al. 2008; MRC 2010).

Currently, most downstream tra catfish farms are only 30 km from the sea mouth, and these farms experience minor salinity variations depending on tidal amplitude. Phan et al. (2009) reported that farms located downstream have lower productivity, which was attributed to salinity fluctuations. With a rise in sea level and reduced water flow it is expected that within the next decade the intrusion of saline water will be evident up to approximately 70 km from the sea mouth and some farms will be subjected to salinities as high as 15‰, making these farms almost unviable. A recent study of farmer perceptions on the vulnerabilities and adaptabilities of such farming communities has indicated that the farmers would not be able to relocate and that the most plausible mitigating measure would be to farm a salinity-tolerant strain of tra catfish (Nagothu et al. in preparation). Technically this is a feasible solution as the currently available molecular genetic tools, using mass selection criteria, support the development of a salinity-tolerant broodstock in a relatively short timeframe (e.g. Guimãres et al. 2007). Moreover, this mitigating measure will also require minimal changes to farming practices and related infrastructure, although suitable hatcheries that will produce salinity-tolerant seed stocks will need to be established.

It is also appropriate to briefly consider the development of striped catfish culture elsewhere in the region, perhaps mooted to a great degree by the success in the Mekong Delta, Vietnam. Striped catfish elsewhere in the region, more commonly referred to as sutchi catfish, has a natural range of distribution in the Mekong and Chao Phraya River basins (Rainboth 1996), and has been widely translocated to other countries and water sheds for aquaculture purposes (Nguyen 2009). Striped catfish farming in Bangladesh has been steadily growing over the past few years and is recognized as a strategy for improving food security and income generation for rural communities (Ahmed & Hasan 2007). Ahmed et al. (2010) reported the economics of three farming systems of striped catfish in rural Bangladesh and reported that annual production was 13 945, 7705 and 3380 kg per ha for intensive, semi-intensive and extensive practices, respectively. These authors reported that the net returns for the three farming systems were, US$ 3364, 2048 and 1099 per ha, respectively. The authors suggested, based on Cobb–Douglas production functions, that inputs are inefficiently used in intensive farming and that there is scope for increasing production and income from the other two farming practices. Striped catfish culture, an exotic species introduced into India, is making rapid progress, with production reaching approximately 200 000 t in 2009 (Lakra & Singh 2010); however, there is considerable concern about its impact on biodiversity.

Conclusions

Aquaculture, although a millennia old tradition, only began to make a significant impact as a major food source in the past few decades, and consequently in the modern day and age, the sector has been subjected to a considerable degree of public scrutiny and policing compared with other food production sectors (De Silva & Davy 2010). It is an era where public demands and expectations on food safety and quality have become paramount, and where increasingly global market forces tend to dictate the destiny of a production sector.

Modern aquaculture has witnessed boom and bust cycles, the most notable of these occurring in shrimp farming in Asia, when the black tiger prawn was adversely impacted by viral diseases. In this case, as well as in other comparable situations, such booms and busts in aquaculture were primarily the result of new disease outbreaks, often related to the intensification of farming practices (Kongkeo & Davy 2010). Solutions to the problems were varied; in this instance success was achieved by the introduction of an alien shrimp, the Pacific white-legged shrimp (P. vannamei), into Asia. The sector survived, with the proviso that the small-scale farmers in the sector were part of the driving force of this survival strategy because of their resilience and adaptability (Kongkeo 1997).

The significance of the tra catfish farming sector in the Mekong Delta has to be considered in the context of the Vietnamese aquaculture sector as well as globally. Vietnam ranks third in aquaculture production globally; in 2008 Vietnam produced a total of 2.462 million tonnes. In 1990 it was ranked 12th and production was only 160 000 t, but in the period 2000–2008 production grew 22.1%, second only to Myanmar (FAO 2010). Fish has also become the most traded food commodity, bypassing
some of the more traditional export commodities, such as coffee, rubber, cocoa, meat, sugar, tobacco and rice, with the net export value increasing globally from US$ 2.9 billion in 1978 to US$ 27.2 billion in 2008 (FAO 2010). Vietnam was the 10th largest exporter of fish and fishery products (both captured and cultured) in 1998 and in 2008 it was ranked 5th in the world (FAO 2010). All this has become possible within the past decade because of the unprecedented development and growth of the tra catfish sector in the Mekong Delta.

Tra catfish farming, although highly intensive, which enables it to attain record production levels averaging 200–400 t ha$^{-1}$ crop$^{-1}$ (Phan et al. 2009), has not been hit with diseases of epidemic proportions. Nevertheless, in view of its high intensive nature, albeit with large potential profits, it is also a very high-risk venture that could be impacted by an increasing number of factors, most significantly farm gate and export prices (Le & Cheong 2010). The tra catfish farming sector, which almost totally targets export markets, has had to and continues to confront various market-driven forces to remain viable; this is indeed a very unusual scenario in aquaculture. However, in view of the importance to the national economy of the country, and the socioeconomic importance to the Mekong Delta at large, a hub of agricultural production in Vietnam, the Government of Vietnam has taken suitable measures to combat these problems, urgently and effectively and to maintain the sector on an even keel. The Government of Vietnam and related authorities, such as the Vietnam Association Seafood Exporters and Producers (VASEP), have to be alert and pro-active to help this sector maintain its momentum.

Khiem et al. (2010) suggested that the vulnerabilities of the tra catfish sector could be categorized into three: global market vulnerabilities, production challenges and governing quality standards. Within each of these, factors such as market diversification, development into export markets and peak oil prices, global financial crisis, feed, water quality, drug and chemical use, seed quality standards, challenges of compliance and governmental policy developments will all play a role and impact on the vulnerability of the sector.

Overall, the tra catfish farming sector is almost unprecedented in the aquaculture sector, perhaps even among all global primary production sectors, in that it is able to produce almost 200–400 t ha$^{-1}$ crop$^{-1}$. It is a sector that has reached these heights within a span of ≤10 years, and indeed has done so, despite major forces acting indirectly to restrain its development. It is a sector that provides many rural households with livelihoods, a higher proportion to women. In poor countries the employment of women not only results in empowerment of households, but also results in a cascading effect that brings social benefits as well as economic benefits to the whole family and ultimately to the whole community (Yunus 2007). Needless to say further improvements in management and more prudent and rationalized usage of water resources are needed, all of which will consolidate the sustainability and well-being of the tra catfish sector in the long term. In all aspects, therefore, the tra catfish sector is an iconic aquatic farming system and its sustainability is crucial to worldwide aquaculture developments.

Perhaps, this is one sector in which development was expedited and achieved when trade issues prevented the export of a relatively small quantity to a nation that farmed another species of catfish. This embargo stimulated the Government of Vietnam to seek new export markets, which it did very successfully; the new market demands were much greater and the Vietnamese farmers and the entrepreneurial processors, with the support of the government, ensured that market demands were met and the sector forgone ahead.

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References


Plate 1  Photos depicting different stages of the tra catfish value chain.  (a) Satellite image showing catfish ponds along the lower branch of the Mekong; note the uniformity of pond size.  (b) Hatcheries may be large scale or small backyard operations.  (c) Stock are fed heavily either by paddling in a boat or as in (d) from a fixed platform.  (e, f) Harvesting is done by specialized crews and live fish are weighed in batches and taken into a boat (g).  (h) A row of boats designed to carry live catfish along a river canal next to a processing plant.  (i–l) Stages in the processing of tra catfish for export (i, bleeding; j, filleting; k, glazing; l, packing).