Analysis of feeds and fertilizers for sustainable aquaculture development in Viet Nam

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SUMMARY

Aquaculture in Viet Nam has become an important economic activity. Total production in 2004 exceeded 1.22 million tonnes, accounting for approximately 40 percent of the country's total fisheries output. Seaweed, fish, crustaceans and molluscs are produced in a wide array of freshwater and marine culture systems at various levels of intensity under mono or polyculture conditions.

Extensive aquaculture is practiced in ponds, rice fields and reservoirs. Chinese, Indian and common carp are the preferred fish in these systems and animal manure is the principal input. Improved extensive and semi-intensive aquaculture is practised in ponds with higher levels of nutrient and feed inputs. Integrated livestock/fish farming is being promoted to optimise the use of on-farm nutrient resources. Intensive aquaculture is undertaken mainly in smaller ponds, cages and tanks. Snakeheads, pangasiid catfish and red tilapia are main species produced in intensive freshwater systems. Trash fish is the most important feed or feed ingredient for snakeheads and pangasiid catfish, while pellets and farm-made feeds are the main inputs in intensive catfish and red tilapia aquaculture systems.

Coastal aquaculture is dominated by black tiger shrimp (*Penaeus monodon*) farming, particularly in the Mekong Delta and coastal provinces of Central Viet Nam. There have been significant advances in the intensification of shrimp farming in Viet Nam. Most shrimp farms are now operated on a semi-intensive scale, while intensive shrimp farming is making rapid advances. Shrimp in intensive systems are fed on commercially manufactured pellet feeds, while semi-intensive and improved extensive system employ trash fish as the major feed ingredient. Other marine species farmed in Viet Nam include eight grouper species, Asian seabass/barramundi (*Lates calcarifer)*, cobia (*Rachycentron canadum*), yellowtail/greater amberjack (*Seriola dumerili*), seabream and snapper and four species of lobster of the genus *Panulirus*. Trash fish is the principal feed for all of the above marine species.

The aquafeed industry in Viet Nam started in 1998. In 2004, the industry produces 300 000–350 000 tonnes of pelleted feed for fish and 150 000–200 000 tonnes of shrimp feed. Despite these developments farm-made feeds still play a vital and major role in Vietnamese aquaculture. Trash fish is the major component of farm-made feeds. However, the supply of trash fish is limiting the development of the sector, unless rapid advances are made to reduce the cost of manufactured feeds. Bulk of fishmeal, soybean meal, wheat flour and marine by-products used by feed manufacturers are imported.

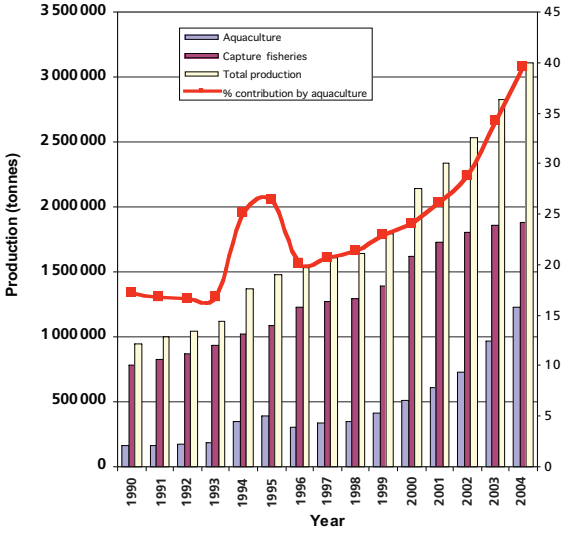
Aquaculture in Viet Nam is targeted to grow at over 20 percent per annum to 2010. To attain this national goal it is essential that aquaculture becomes more intensive. It also means that more feed and nutrient inputs are needed and this poses several challenges that have to be met. The challenges revolve particularly around the availability and supply of feed ingredients and the dwindling supply of trash fish. For the sector to develop in a sustainable manner there is a need to focus on alternatives to fishmeal and trash fish, farmer education and for government to formulate enabling policy and legislation to facilitate the development of the aquatic feed industry.

1. GENERAL OVERVIEW OF AQUACULTURE PRACTICES AND FARMING SYSTEMS

1.1 Current status of aquaculture

The inland and marine aquatic resources of Viet Nam are ideally suited for aquaculture development. The country has a coastline of around 3 260 km, 12 lagoons, straits and bays, 112 estuaries and thousands of islands in the China Sea. Inland waters include a network of rivers, canals, irrigation systems and reservoirs amounting to about 1.7 million ha that consists of 120 000 ha of ponds, lakes and canals, 340 000 ha of reservoirs, 580 000 ha of paddy fields in which aquaculture is integrated with rice farming and 660 000 ha of tidal waters.

FIGURE 1
Fisheries and aquaculture production in Viet Nam during 1990 and 2004



Source: FAO (2006)

TABLE 1
Fisheries and aquaculture production (tonnes) and their export value (thousand US$) during 2002, 2003 and 2004 and target for 2010

Sectors	2002	2003	2004	2010
Total fisheries production	2 530 639	2 823 607	3 108 105	-
Aquaculture production	728 041	967 502	1 228 617	2 000 000
- Inland aquaculture	441 827	547 931	703 827	946 000
- Brackish & marine	286 214	419 571	524 790	1 054 000
Export value of fisheries and aquaculture production	-	2 199 577	2 397 000	-

Source: Production data from FAO (2006) and export value data from MOFI (2004)

The total fisheries production of Viet Nam reached about 2.53 million tonnes in 2002 and increased to more than 3.1 million tonnes in 2004, of which more than 1.22 million tonnes was from aquaculture (FAO, 2006). Figure 1 shows the development of aquaculture in Viet Nam between 1990 and 2004. Freshwater aquaculture is the largest contributor to total aquaculture production (57.3 percent), followed by brackish-water aquaculture with 27.6 percent and mariculture with 15.1 percent. Since 1990 aquaculture production has been increasing continuously over the years and Viet Nam is currently acknowledged as having the fastest aquaculture growth rate in Asia. The target of the national fisheries development plan is for Viet Nam to produce 2.0 million tonnes of aquaculture produce in 2010 (Table 1) (MOFI, 2004).

Capture fisheries seem to be reaching a plateau. Fortunately the rapid increase in aquaculture production has compensated for the production gap such that the country can meet the increasing demand of its domestic and international markets.

1.2 Inland Aquaculture

Inland aquaculture in Viet Nam is well developed and in 2004 accounted for 57 percent of national aquaculture production (FAO, 2006). The sections below describe the various systems that are in use and the species that are cultured in them.

Pond culture is the most common aquaculture practice in the country. The main aquaculture species include common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), Indian major carps (*Labeo rohita, Cirrhinus cirrhosus*), tilapias (Mozambique tilapia *Oreochromis mossambicus* and Nile tilapia *O. niloticus*),

TABLE 2
Catfish area and production trends in the Mekong Delta

Category	1997	1999	2001	2003	Estimated 2004	Growth rate %/year
Culture area (ha)	**1 290**	**2 253**	**2 305**	**2 717**	**3 200**	**24.6**
- Pond (ha)	1 290	2 253	2 288	2 652	2 991	21.9
- Cage (unit)	1 300	1 621	2 539	2 271	1 872	7.3
Production (tonnes)	**40 250**	**86 775**	**114 289**	**162 778**	**255 044**	**88.9**
- Pond	22 550	50 330	66 660	109 105	178 624	115.3
- Cage	700	19 005	37 418	48 068	45 748	-

*Culture area includes both ponds and pens and so the values in some cases slightly differ from that of pond area. Cage area have not been included in the culture area.

Source: MOFI (2004)

hybrid clariid catfish (*Clarias macrocephalus* x *C. gariepinus*), and Mekong catfish (tra catfish *Pangasius hypophthalmus and* basa catfish *P. bocourti*). Pond culture is practiced at different levels of intensity. At the household level most small-scale farmers practice extensive polyculture in fertilized ponds, in which the fish rely entirely on natural food. Cyprinids and tilapias are the most commonly used species in these systems. Semi-intensive and intensive practices are geared more towards the production of high value fish and freshwater prawns, such as hybrid clariid catfish, pangasiid catfish, giant snakehead (*Channa micropeltes*), red tilapia (hybrid between Nile tilapia and Mozambique tilapia), kissing gourami (*Helostoma temmincki*) and giant freshwater prawn (*Macrobrachium rosenbergii*).

Cage culture is practised along the Mekong River, its tributaries (the Tien and the Hau) and in the Delta and in reservoirs. Cage culture is permitted only in the larger reservoirs such as Hoa Binh (19 000 ha), Thac Ba (18 000 ha), Tri An (32 400 ha), Thac Mo (10 600 ha) and Dau Tieng (18 000 ha). Reservoir cage culture species include grass carp, marble goby (*Oxyeleotris marmorata*), snakehead, common carp, hybrid clariid catfish and red tilapia, while the species grown in cages in the Mekong river and delta include three species of pangasiid catfish (*P. bocourti*, *P. hypophthalmus* and *P. conchophilus)* as well as hybrid clariid catfish (Tuan, 2003).

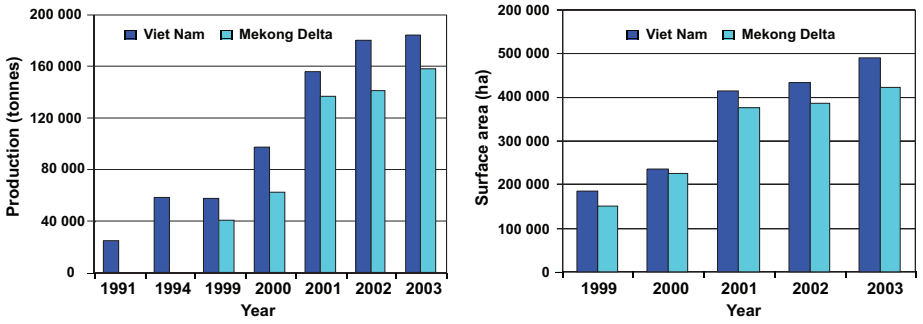
Pen culture of pangasiid species, particularly *P. hypophthalmus,* is a relatively new practice that is being developed, along with pond culture, for pangasiid catfish in the Mekong Delta marshes. Some 30 672 tonnes of catfish were produced in pens in 2004. Pen culture of *P. hypophthalmus* already contributes 12 percent of total pangasiid catfish production in the Delta.

The Mekong Delta is the most important freshwater aquaculture region in Viet Nam and therefore requires special mention. Many culture practices are applied and various fish species are cultured in this area. Indian major carps, Chinese carps, silver barb and tilapia are produced for domestic consumption, while pangasiid catfish, marble goby and freshwater prawns are exported. Freshwater prawn farming in the Delta has led to substantial diversification of farming practices, such as the increase in rice fields and integrated rice-prawn farming systems. Mekong catfish farming in the Delta has expanded at an extremely rapid rate (Table 2) and is unquestionably the most important species in the Delta. Production in 2004 was around 280 000 tonnes, accounting for 56 percent of freshwater aquaculture production in the Delta and about 10 percent of the national aquaculture export value (Phuong *et al*., 2005).

1.3 Coastal Aquaculture

Coastal aquaculture is dominated by pond culture of black tiger shrimp, particularly in the Mekong Delta and the central provinces of Viet Nam. The diversity of coastal aquaculture is however best summarized on a regional basis. The marine species farmed in Viet Nam are described by Tuan (2003).

FIGURE 2
Production and pond surface area of shrimp farming in Viet Nam and the Mekong Delta



Source: MOFI (2003)

1.3.1 Coastal aquaculture in the Mekong Delta

The rapid development of shrimp farming in the Mekong Delta since 1999 is illustrated in Figure 2. Marine fish, brine shrimp (*Artemia*) and mud crab are also commonly cultured species in the Delta. Between 1999 and 2003 total shrimp farming area had increased by more than 2.8 folds (160 000 ha to 450 000 ha) and production by over 3.8 times during this period. In 2003, about 450 000 ha were dedicated to shrimp farming in the Delta and production had reached 162 000 tonnes (MOFI, 2003) Currently the Delta is responsible for 86 percent of national shrimp production and comprises about 87 percent of the country's total shrimp pond area.

Shrimp farms include extensive, improved-extensive, semi-intensive and intensive systems. Extensive shrimp farming (80–250 kg/ha/year) is being gradually replaced by semi-intensive and intensive systems, with higher production levels of 6–10 tonnes/ha/crop. Rice-shrimp farming is also widely practiced, which has several advantages and synergistic effects.

1.3.2 Coastal aquaculture in the central provinces

Tiger shrimp is also the most important aquaculture species in the coastal areas of the central provinces. In 2003, this region had some 16 931 ha under shrimp ponds and shrimp here are farmed intensively (MOFI, 2004). Lobsters and groupers are cultured in cages. Edwards, Tuan and Allan (2004) reported that lobster (*Panulirus* spp.) cage culture was more profitable than grouper culture. In Khanh Hoa province there are over 12 000 lobster farms. Lobster culture is mainly a family enterprise, with each family owning one or more cages that are deployed in coastal lagoons or sheltered bays. Cages are typically 10–30 m^3 in volume, constructed with synthetic netting stretched over a bamboo frame. Floating cages, supported by plastic drums, are also used. Families tend to aggregate their cages in areas where water quality is good and to benefit from lower labour costs and improved security (Hambrey, Tuan and Thuong, 2001). Other species cultured in the central provinces include red grouper, black grouper, snapper, shrimp and ornamental fish.

1.3.3 Coastal aquaculture in northern Viet Nam

Coastal shrimp and fish aquaculture activities in northern Viet Nam are concentrated mainly in the Gulf of Tonkin. Cat Ba Island, Ha Long Bay, Do Son (Hai Phong province), Quang Ninh, Nam Dinh, Ninh Binh, Thai Binh, Thanh Hoa, Nghe An and Ha Tinh. Cage culture of Asian seabass (*Lates calcarifer*) and cobia (*Rachycentron canadum*) is mostly located on Cat Ba Island and in Ha Long. Trash fish is the main feed used in cage culture. Trash fish food conversion ratios (FCR) are high (6–8:1) and some farmers are now also using pelleted feed. Both tiger shrimp and Pacific white

shrimp (*Litopenaeus vannamei*) are farmed in northern Viet Nam, mainly around Quang Ninh, Hai Phong, Nam Dinh, Ninh Binh, Thai Binh, Thanh Hoa, Nghe An and Ha Tinh.

2. ON FARM FEEDING PRACTICES AND FEED MANAGEMENT STRATEGIES

2.1 Inland Aquaculture Systems

A total of 29 species (14 indigenous and 15 introduced) are farmed in freshwaters in Viet Nam (Table 3).

More than 70 percent of the freshwater aquaculture species are omnivores and include, amongst others Mekong catfish, hybrid clariid catfish, Indian major carps, kissing gourami (*Helostoma temminkii*) and red tailed tinfoil/silver barb (*Barbonymus altus*) (Table 4). All the cultured carnivorous species are indigenous and high value species such as snakehead (giant snakehead *Channa micropeltes* and snakehead murrel *C. striata*), marble goby and spotted bronze featherback (*Notopterus notopterus*). Almost all of the filter feeders are introduced species. Overall, omnivorous species are the most favoured because they are able to feed on a variety of feeds such as rice bran, fresh manure, cooked rice, trash fish, vegetables, restaurant waste, etc. (Hung, 2004).

2.1.1 Pond fish culture

Pond culture of herbivorous fish

Herbivorous fish are preferred in household-scale culture systems that primarily produce fish for home or local consumption. In particular grass carp and silver barb are popular species and they are fed on aquatic plants and grass, which are abundant, and supplemented with rice bran, manure, restaurant waste and household waste when available.

Pond culture of filter feeders

Silver and bighead carp, catla, rohu and sometimes tilapia are classified as filter feeders, although tilapia can also be considered an omnivore. Polyculture systems have been developed for the culture of filter feeders in which farmers raise 3–5 species in fertilized ponds. Silver and bighead carp are favoured in northern Viet Nam and the central Highland, while catla and rohu are preferred in the Mekong Delta.

Animal manure (pig, duck, chicken and cattle) is the main input for polyculture systems in Viet Nam. The use of manures is diverse and is described below. However, farmers lack knowledge of application procedures and rates. Except in fingerling ponds, farmers rarely use inorganic fertilizers to stimulate natural productivity (Hung, 2004).

TABLE 3
Families and the number of freshwater aquaculture fish species in Viet Nam

Family	Total number of species	Indigenous species	Introduced species
Cyprinidae	12	3	9
Pangasiidae	4	4	-
Ophicephalidae	3	3	-
Cichlidae	3	-	3
Anabantidae	4	2	2
Clariidae	3	2	1
Total	**29**	**14**	**15**

Source: Hung (2004)

TABLE 4
Feeding guilds of freshwater aquaculture fish species in Viet Nam

Feeding guild	Species
Herbivores (3)	Grass carp, snakeskin gourami (*Trichogaster pectoralis*), silver barb (*Spinibarbus denticulatus*)
Filter feeders (4)	Silver carp, bighead carp, tilapias
Omnivores (21)	Mekong catfish (*P. hypophthalmus, P. bocourti*), hybrid clariid catfish, Indian major carps, giant gourami (*Osphronemus goramy*), kissing gourami, silver barb, etc.
Carnivores (5)	Snakeheads (*Chana gachua, C. micropeltes, C. striata*), marble goby, bronze featherback (*Notopterus notopterus*).

Number within parenthesis is the number of species under the specified feeding guild.

2.1.2 Animal-fish integrated systems

Integrated fish-livestock farming is widely practised throughout the country. Most common is the pig-fish combination. Waste products from pig production are the main source of nutrient input. Herbivores and planktivores make optimum use of algal and zooplankton blooms, while omnivores make direct use of the pig manure. In this way, farmers maximize the use of on-farm resources without additional cost for feeds. Pig stocking density is usually in the range of 150–200 pigs/ha of fishpond with an initial weight of 30–50 kg. Fish are usually stocked at a density of 7 fish/m^2. Pig "compost" can also be obtained from biogas generators, which is then used for pond fertilization. Under these conditions the fish are normally fed with rice bran (50–70 percent) and crab, golden snail or other fish or agricultural processing by-products. Typical production figures of several livestock-fish combinations are provided in Table 5.

TABLE 5
Fish production in various freshwater farming systems

Farming systems	Yield (tonnes/ha/crop)
Rice-fish integrated	0.43–0.80
Pig-fish integrated	3.88–7.59
Fish-rice alternative	0.60–0.90
Prawn-rice alternative	0.75–0.80
Prawn-rice integrated	0.35–0.50

Source: Wilder and Phuong (2002)

VAC systems (V="Vuon" or garden, A="Ao" or fishpond, C = "Chuong" or pig coop) are also popular. The system is designed to optimally use most on-farm waste resources. Main feed inputs to fish ponds are agricultural by-products such as rice bran, vegetable, cassava leaf, corn meal, etc. and waste (manure and uneaten food) from the pigs. Fish produced in the VAC systems are normally low value fish used for household consumption or for sale in local markets. Grass carp, common carp, silver carp and Indian carps are commonly used.

2.1.3 Rice-fish integrated system

The Mekong Delta has more than 1.0 million ha of rice paddies, of which 400 000 ha are suitable for developing rice-fish culture (Tuan *et al*., 1995, cited by Hao *et al*., 2000). However, many factors such as flooding and low rice prices have affected rice-fish integrated farming systems in the Delta and consequently the practices have been diversified. Many fish species are cultured in rice fields. These include high-value species such as snakeskin gourami (*Trichogaster pectoralis*), climbing perch (*A. testudineus*), catfish (*P. hypophthalmus*) and freshwater prawn (*M. rosenbergii*) as well as low value species such as silver barb, tilapia and Indian carps. Silver barb is particularly suited to rice-fish systems as it survives and grows well. Moreover, fish or prawn culture can be alternated with rice cultivation (Wilder and Phuong, 2002).

Inorganic fertilizers are most commonly used in rice-fish systems. In a survey of 262 fish farms in the Mekong Delta, Long (2002) found that the application rates of inorganic fertilizer into the systems were extremely low ranging between 82–105 kg/ha/year. Urea was most commonly used. Organic fertilizers are not widely used in the rice-fish systems. A variety of feeds are used to supplement natural foods and include amongst others rice bran, broken rice, waste vegetable, water spinach and sweet potato leaves. Fish yield depends on whether the fish receive supplemental feed or not and varies from 50–150 kg/ha/year under no feeding conditions to over 300 kg/ha/year with supplementary feeding.

2.1.4 Giant freshwater prawn (Macrobrachium rosenbergii)

Existing culture systems of *M. rosenbergii* include improved-extensive culture in rice fields, and semi-intensive and/or intensive culture in ponds, orchard canals and pens.

Pond culture

Giant freshwater prawn are fed on pellets and farm-made feeds. Farm-made feeds consist of trash fish, golden snail, rice bran and other ingredients. Trash fish is only incorporated into the feed when golden snails are scarce. During the first month

the prawns are fed exclusively on pellets and for the remaining five months they are normally fed a combination of pellets (40 percent) and farm-made feed (60 percent). The ration decreases with age from around 30 percent of pond biomass for the first week after stocking to around 8–10 percent between weeks 9 and 24 and the prawns are fed 4 times per day and consumption is monitored (Long, 2003). Yields vary from 500–1 200 kg/ha/cycle (MOFI, 1999).

Rice-prawn integrated system
Besides the Mekong Delta where rice-prawn farming systems are common, farmers in northern Viet Nam have also recently adopted this practice (Trang, Thanh and Phuong, 2004). Rice fields are usually fertilized to stimulate the growth of the rice and of natural food. Animal manures and green fodder (wet composting) are widely used as fertilizers. Animal manures are only applied after composting at a rate of 20–30 kg/100 m^2 and green fodders are applied at the same rate. No supplemental feeds are provided to the rice-prawn systems in northern Viet Nam. By contrast, farmers in the Mekong Delta usually provide supplementary feed in the form of pellets and farm-made feeds. Farm-made feeds and feeding schedules are identical to those described in the previous section and yield varies from 300–500 kg/ha/crop. A recent study in Can Tho showed that farmers can obtain up to 600 kg/ha of prawns in the winter-rice crop by feeding a 9:1 mixture of golden snail and pellets (Hien, 2004).

Pen culture of prawn
Pens range in size between 100 and 900 m^2 and prawns are usually stocked in June at an average density of 62/m^2. Pen culture is practiced on a multiple harvest strategy to maximize productivity and prawns are harvested every 2–4 months starting from the 4th month after the initial stocking. Harvesting lasts until late December or January. Average prawn yield is 0.52 kg/m^2/year, Farm-made feeds are made from locally available ingredients such as snails, mud crab, trash fish, rice, coconut meal and cassava roots and fed twice a day at 22 percent of body weight per day (Son, Yi and Phuong, 2005).

2.1.5 Cage culture of fish
A variety of species are farmed in cages. Grass carp are produced in small cages along rivers or in reservoirs in northern Viet Nam, the central highlands and southeastern Viet Nam. Feed consists of locally available grasses. FCR is as high as 40:1 on a wet weight basis. In intensive cage culture, grass carp can be fed on other feeds such as paddy sprouts, sweet potato, cassava and cassava leaves.

Giant snakehead, *C. micropeltes* is preferred by consumers and is cultured only in cages, while snakehead murrel (*C. striata)* is cultured only in ponds. Chopped trash fish is the sole feed for these fish and FCR ranges from 4.5–5:1. The recent proliferation of snakehead culture has become problematic as the capture of juveniles is affecting the conservation status of the species and of wetland biomes.

Cage culture of red tilapia is a recent initiative (1999), particularly in the peri-urban areas of Ho Chi Minh City and other cities. Red tilapia production in peri-urban areas of Ho Chi Minh City has increased from 300 tonnes in 2000 to 4 200 tonnes in 2004 and this is a substantial proportion of national red tilapia production, which in 2004 reached 15 000–20 000 tonnes. Farmers raise fingerlings in earthen ponds until they reach 50–100 g and then transfer them to cages, which vary in size from 60–120 m^3. Commercially formulated pellets are the main feed. Protein levels in the feeds range from 35–40 percent for fingerlings and 22–25 percent for growth-out. The fish are reared for 4–5 months to a marketable size of 0.6–1.0 kg. The fish are fed 3–4 times per day, following the feeding schedule of the manufacturer. FCR's using formulated feeds range between 2.2–2.5:1. Farm-made feeds are rarely used in tilapia cage culture (Hung, Truc and Huy, 2007). Yields are high and range from 100–150 kg/m^3/year.

TABLE 6
Technical parameters for *Pangasius* cage culture

Parameters	Description
Unit size (m^3)	96–576
Species cultured	*P. hypophthalmus, P. bocourti*
Feed used	Farm-made feed in combination with pellets in early months of rearing
Feeding strategy	2–3 times/day, 3–5 % body weight/day
Yield (kg/m^3/5–7 month cycle)	150–200

Source: Hung, Truc and Huy (2007)

The Mekong Delta is the main area for cage culture of pangasiid catfish, particularly *P. hypophthalmus*, *P. bocourti* and *P. conchophilus*. A detailed comparative account of pangasiid cage and pond culture in the Mekong Delta is provided by Hung, Truc and Huy (2007). Table 6 summarizes some technical parameters of pangasiid cage culture.

2.1.6 Intensive pond culture of fish

Pond culture of carnivorous fish is a common practice in Viet Nam. Snakehead, *Chana striata* is one of the main carnivorous species, which is intensively cultured in ponds in Viet Nam. Farm-made feeds are preferred and pelleted feeds are rarely used. Farm-made feeds with a protein content of at least 40 percent are made from trash fish, snails, small shrimps and chopped squid as protein sources and mixed with rice bran, broken rice or corn bran as well as vitamins and minerals to form moist pellets. The fish are fed twice a day on a ration of 4–5 percent biomass per day. At present, the practice is heavily dependent on trash fish.

Hybrid clariid catfish are raised mainly with restaurant wastes and animal manure. As mentioned previously the fish is commonly used in integrated livestock systems as they can effectively utilize livestock waste and can survive in poor water quality. Ground and mixed slaughterhouse waste such as poultry bones and intestines, livestock bones, restaurant waste, shrimp head waste, fish processing waste can also be used for hybrid catfish.

Pangasiid pond culture has developed rapidly in recent years, particularly since the successful artificial breeding of tra catfish (*P. hypophthalmus*). The high cost of cage culture has also contributed to the development of pond culture. Hung, Truc and Huy (2007) provide a detailed comparative account of pangasiid pond, pen and cage culture (see also Phuong, Minh and Tuan, 2004). Table 7 summarizes some of the comparative detail.

Giant gourami (*Osphronemus goramy*) is cultured mostly in ponds in southern Viet Nam and fed on aquatic or terrestrial plants. Even though the fish is classified as a herbivore, it readily consumes mixed farm-made feeds and pellets. By using pellets the production cycle can be reduced from 15–18 months to 8–10 months. The fish are grown mainly in peri-urban areas to supply restaurants and middle-class markets (Hung, 2004) and pond culture of gourami is often combined with morning glory culture (Huy, 2003).

TABLE 7
Technical description of pangasiid pond and pen culture in the Mekong delta

Description	Pond culture	Pen culture
Pond size	0.3–1.0 ha	0.3–0.5 ha
Culture period (month)	6.25±0.87	5.6±0.8
Stocking density (nos./m^2)	20.5±10.0 (15–35)	34.8±8.1
Feeds	farm-made feeds & pellets	farm-made feeds & pellets
Survival rate (%)	94.0±2.20	82.6±4.0
Productivity (tonnes/ha/crop)	150–-350	345±149

Source: Phuong, Minh and Tuan (2004)

2.2 Coastal aquaculture systems

2.2.1 Pond culture of tiger shrimp

Shrimp culture in central Viet Nam is mainly intensive, whereas in the north and in southern Viet Nam it continues to range from extensive to intensive. The different systems require different feeding strategies and feeds.

Extensive system

Extensive shrimp farming is a traditional farming practice in the Mekong Delta and other coastal provinces. In extensive systems water is exchanged tidally with the inflow bringing natural seed and feed to the culture ponds. Twice a month during the low spring tide, shrimp and fish are harvested as they move down with the water current to the sea. Feeding is not practiced in extensive systems and shrimp rely on naturally available foods. Until about 10 to 15 years ago natural seed abundance of *Penaeus merguensis and P. indicus* was sufficiently high to supply the ponds with juveniles. Recently farmers have had to stock tiger shrimp PLs to improve their yields due to a decline of natural seed. This is known as the improved extensive system. The two systems occupy a large proportion of shrimp culture surface area in Viet Nam and particularly in the Mekong Delta. In 2003, extensive and improved extensive systems accounted for 68 percent and 27 percent of the shrimp farming surface area in the Mekong delta, respectively (Phuong, Minh and Tuan, 2004).

Semi-intensive and intensive systems

In semi intensive systems the natural food is supplemented with trash fish, small shrimp (*Acetes sp*.) and low price shrimp pellets. Stocking density ranges form 5–10/m^2. Aeration is not used. The systems may be operated on shrimp/rice rotation basis or integrated with mangroves. There are 20 500 ha of semi-intensive shrimp farms in the Mekong delta (MOFI, 2003).

In the intensive systems, shrimp are stocked at 20–50 Post Larvae (PL) per m^2. The system requires a high level of maintenance and management with respect to feeding, water quality control, the controlled use of antibiotics and aeration. Though most farmers use commercially formulated shrimp feeds in these systems, some still follow traditional methods of improving yields by using fertilizer to stimulate plankton growth and adding trash fish. The total surface area under intensive culture in 2003 was 15 534 ha (MOFI, 2004). The main species in the Mekong Delta is tiger shrimp, while Pacific white shrimp *L.vannamei* has now been introduced to farms in central Viet Nam. Stocking densities for white shrimp (95 PL/m^2) are much higher than for tiger shrimp (18 PL/m^2).

Formulated feeds are most often used in intensive systems, though some farmers combine formulated and farm-made feeds during the final days of the production cycle. Farm-made feeds include cooked trash fish, small shrimp and molluscs. A study in Quang Ngai province of central Viet Nam shows that 30 percent of farmers still use farm-made feeds in intensive tiger shrimp culture, but not for white shrimp (Nhan, 2005).

Farmers use feeding trays (2–4 trays per 4 000–5 000 m^2 pond) to monitor consumption and to adjust the ration. Pellets are broadcast over the pond surface 2 to 3 times per day using a boat or floating raft. All feed producers provide feeding tables to avoid over or under feeding. Table 8 is an example of a recommended feeding strategy. Daily feed is adjusted according to shrimp size and the remaining portion of feed on the feeding tray. Under good management FCRs for commercially formulated feeds range from 1.3–1.5:1. In poorly managed systems FCR can be as high as 2.5:1. Under intensive culture conditions yields of up to 7 tonnes/ha/crop can be attained.

TABLE 8
Manufacturer recommended feeding schedules for intensive shrimp culture using formulated feeds

Stage	Shrimp size (g)	Feeding rate[1]	% feed distributed on feeding trays	Feeding tray monitoring intervals (hrs)
PL_{20}–PL_{27}	<0.2	1.0–1.5 kg/90 000 post larvae per day	NA	NA
PL_{28}–PL_{35}	0.2–0.6	1.5–2 kg/90 000 post larvae per day	NA	NA
PL_{36}–PL_{45}	0.6–1.5	6 – 6.5	2	3
PL_{46}–PL_{55}	1.5–5.0	5.5	2.4	2.5
PL_{56}–PL_{75}	5.0–10.0	4.5	2.8	2.5
PL_{76}–PL_{95}	10.0–20.0	3.8	3.0	2
>PL_{95}	>20.0	3.5	3.3	2

[1] Percent body weight per day unless otherwise indicated; NA = not applicable

Source: Ocialis Feed Company, Viet Nam (pers. com.)

2.2.2 Rice-shrimp alternating system

Alternating rice with shrimp culture is typical in many places in the Mekong Delta. The system was developed because of saltwater intrusion into rice fields during the dry season. During this period shrimp are stocked into the paddy fields and reared under improved extensive or semi-intensive conditions. Some output data from these systems is provided in Table 9.

TABLE 9
Some technical and economical parameters of alternating rice-shrimp culture in the Mekong Delta

Parameters	Data
Pond area (ha)	1–2
Water surface (%)	25–30%
Water level in rice field	30–50 cm
Seed	Hatchery produced seed (PL_{15})
Stocking density (piece/m^2)	2–-55 PLs/m^2
Cropping season	January – May
Feed	Pellet and farm-made feeds
Fertilization	Lime and fertilizer
Average survival rate	10–33%
Production (kg/ha/year)	300–450
Total cost (VND million/ha/crop)	10–15
Total revenue (VND million/ha/crop)	30–45
Benefit-/-cost ratio	2.5–3.0

US$1.00 = VND 15 800

Source: Phuong, Minh and Tuan (2004)

In these systems fertilizers are only applied when phytoplankton does not develop naturally. Farmers prefer chicken manure that is packed in bags and immersed. Inorganic fertilizer (NPK (nitrogen, phosphorus and potassium) 20:20:15 and urea (46 percent) at a 4:1 ratio) is only used when organic fertilizers are unavailable and is applied at 3–5 kg/1 000m^2.

The price and nutritive quality of feeds used in these systems is lower than those used in intensive systems. Several manufacturers produce specific feeds for rice-shrimp systems. Farmers usually use commercially formulated feed in the first month where after they use farm-made feeds. A recent study has found that the use of farm-made feeds in these systems is wasteful and environmentally not sustainable and recommends that formulated feeds only be used when natural food is limiting (Burford *et al*., 2004). Shrimps are fed 3–4 times per day and the ration is adjusted according to shrimp size and appetite (Preston and Clayton, 2004).

2.2.3 Marine fish and lobster

Marine fish and lobster are mainly cultured in floating cages in central and northern Viet Nam. Besides cage culture, marine fish and mud crab are also cultured in earthen ponds

Lobster

The preferred feeds for lobster cage culture are molluscs, crustaceans and trash fish (preferably red big-eye, pony fish and lizardfish). FCRs range from 28–29:1. The feeding regime is size dependent. Small lobsters are fed 3–4 times per day with a higher feed amount in the evening. Trash fish is chopped into small pieces, while molluscs are removed from their shells. At 400g and larger they are fed twice daily and feeding

intensity is substantially increased before moulting. During the last few months the proportion of molluscs and crustacean is increased, while trash fish is decreased (Tuan, 2003). Feeding practices may vary from one place to another. For example, Edwards, Tuan and Allan (2004) report that lobsters in some areas are fed once per day and farmers alternate between trash fish, snails, clams and small crustaceans on a daily basis to maintain optimum food intake. Lobsters also adapt well to formulated feeds, though water stability and price largely preclude the use of pellets (Edwards, Tuan and Allan, 2004). Cages vary in size from 3–50 m^2 (bottom area) and 2–3 m in depth with a submerged depth of 1–1.5 m (Tuan, 2003).

Grouper and cobia culture

Grouper are cultured in cages and in earthen ponds. Stocking density in cages may be as high as 25 fish/m^3 but can be adjusted accordingly to size of the seed. The main feeds are trash fish, shrimp and crabs. Despite its high price (VND 3 000–10 000/kg), the preferred trash fish for grouper is anchovy. If anchovy is in short supply farmers use pony fish at around half the price. The fish are fed twice a day at dawn and dusk on a daily ration of 3–10 percent fish biomass. Trash fish is used whole or chopped according to the mouth size of the fish. Trash fish is sometimes boosted with a vitamin and mineral premix at 0.5 percent of feed weight. Decayed or rotten trash fish is not used for grouper culture. Recent work by Edwards, Tuan and Allan (2004) has shown that trash fish for grouper as well as cobia is the most cost effective, though MOFI is concerned about the level of pollution caused by the use of this food in grouper and cobia culture. Presently, grouper and cobia culture is entirely dependent on trash fish. The reduced availability of this commodity has now forced many farmers to reduce their feeding frequency to once every four days. Interestingly, growth rate has not been significantly affected and this practice reduces the impact of cage culture on the environment (Thanh, 2005).

Pond culture of grouper is a recent initiative and investment costs are lower than cage culture. The FCR of grouper in ponds (4.3:1) is lower than in cages (Trai and Hambrey, 1998).

3. REVIEW OF THE AQUAFEED INDUSTRY

Aquafeed production in Viet Nam started in 1998 when several animal feed manufacturers recognized the opportunities. The domestic animal feed industry is well established. Currently only shrimp and pangasiid catfish feeds are made (Hung, 2006). The aquafeed industry is reviewed in the context of its present status, opportunities and constraints to support the sustainable development of aquaculture.

3.1 Animal feed Industry

Commercial animal feed production has grown at an annual rate of 10–13 percent. In 2003 Viet Nam produced 3.8 million tonnes of animal feed, of which 70 percent comprised complete feeds and 30 percent of concentrates (which the farmers mix with on-farm ingredients). Current production does not meet the domestic demand (Table 10). The industry relies heavily on imported feed ingredients, including soybean meal, corn, fishmeal, meat and bone meal, rice and wheat bran and feed pre-mixes and vitamins (Huong, 2004).

According to MARD there were 182 animal feed and premix manufacturers operating in Viet Nam in 2003. Of these 138 are fully fledged animal feed mills that produce complete feeds as well as feed concentrates. The total production capacity of the animal feedmills is estimated at 5 million tonnes per annum, which falls short of the demand (Table 10). Fifteen of the 138 feedmills are either wholly owned subsidiaries of foreign companies or are joint ventures and these companies hold more than 50 percent of the animal feed production capacity in Viet Nam. Key companies include Proconco

a Viet Nam - French joint venture), CP Group of Thailand, Cargill of the United States of America, Uni President of Taiwan Province of China and the Cheil Jedang Group of South Korea (Huong, 2004).

Because of the rapidly increasing demand for aquafeeds, animal feed manufacturers have shifted their production lines to produce aquafeeds mainly for shrimp and pangasiid catfish.

TABLE 10
Animal feed requirements and production in 2000-2002 (thousand tonnes)

Year	2000	2001	2002
National animal feed requirement	8 200	8 500	8 900
Total animal feed production	2 700	3 000	3 400
Complete feed	1 700	1 950	2 400
Feed concentrate	330	350	340

Source: Ministry of Agriculture and Rural Development, MARD (pers. com.)

3.2 Shrimp feeds

The shrimp feed industry is in its infancy. Activities began in 1998 with an annual production of 10 000 tonnes per year. The current demand for commercial shrimp feeds in Viet Nam is about 150 000–200 000 tonnes per year. Although the bulk of the demand can theoretically be met by domestic production, approximately 3–5 percent still has to be imported (Hung, 2006).

There are 36 aquafeed-mills in Viet Nam, 23 of which produce shrimp feed. Five multinational companies each with an installed capacity of 20 000–40 000 tonnes per annum, dominate shrimp feed production in the country. In addition to the larger companies, there are about 10 smaller, locally owned companies that manufacture shrimp feeds. These feed mills have an installed capacity of 5 000–10 000 tonnes per year. However, many of them are not adequately equipped to produce good quality feed. Most of the local companies simply adapted their livestock feed equipment to produce shrimp feed and found that such modifications seldom worked well. As a result, many are now planning to install dedicated shrimp feed manufacturing equipment. The main producers of shrimp feed, their location and capacity are listed in Table 11.

The total capacity of shrimp feedmills in Viet Nam is in the range of 300 000–400 000 tonnes per annum, which currently exceeds demand. Despite the over-capacity, further growth in the country's shrimp feed industry is expected due to following reasons (Hung, 2006):

- the seasonal nature of shrimp farming, produces a peak in demand during the summer months that exceeds installed capacity. Stronger companies with high market share are expanding their feedmill capacity; and
- the intensive shrimp farming sector, though occupying less than 10 percent of national shrimp pond surface area consumes 80–90 percent of formulated feeds. Further intensification of shrimp farming in the country provides enormous scope for growth of the feed industry.

TABLE 11
List of main shrimp feed producers in Viet Nam

Company	Ownership	Location	Capacity (tonnes/year)	Year of commencement
C J Vina Agri	South Korea	Long An	12 000	2003
Ocialis	France	Binh Duong	10 000	2003
Asia Hawaii	Joint venture (VN-USA)	Phu Yen	20 000	2002
Uni-President	Taiwan Province of China	Binh Duong	60 000	2001
Uni-Long	Taiwan Province of China	Nha Trang	20 000	2000
Grobest	Taiwan Province of China	Dong Nai	25 000	2001
CP group	Thailand	Dong Nai	30 000–40 000	2001
Tom Boy	Taiwan Province of Chin	HCM city	30 000	2002
Cargill	USA	Dong Nai	10 000	2001
Proconco	Joint venture (VN-France)	Can Tho	12 000	2000
Cataco	Viet Nam	Can Tho	12 000	2003
Dabasco	Viet Nam	Can Tho	20 000	2002
Seaprodex	Viet Nam	Da Nang	15 000	1990

Source: Serene and Merican (2004)

TABLE 12
Nutrient composition of commercial shrimp feed (% dry matter basis)

Stage	Moisture	Crude protein	Crude lipid	Crude fibre	Ash	Calcium	Phosphorus
Post larvae	<11	>43	>5	<3	<16	>2.5	>1.5
Starter	<11	>41	>6	<3	<16	>2.5	>1.5
Grower	<11	>38	>6	<3	<16	>2.5	>1.5
Finisher	<11	>36	>6	<3	<16	>2.5	>1.5

Source: Ocialis Feed Company, Viet Nam (pers. com.)

Most shrimp feedmills in Viet Nam are located in the vicinity of Ho Chi Minh City. Its port and accessibility to markets provide distinct advantages to feed manufacturers. Almost all major shrimp feed ingredients including soybean meal, fishmeal, flour, fish oil and feed additives are imported. Besides the average import duty of 10 percent, all ingredients and feed additives carry value-added tax (VAT) at five percent, except for soybean meal.

In 2004, the Ministry of Fisheries published a quality standard for shrimp feed (28 TCN 102: 2004) that obligates feedmills to comply with certain minimum standards (Appendix A.1.). According to the standard, crude protein content of the manufactured feeds should be 35 percent for grow-out shrimp (>20g) and up to 42 percent for beginner feeds (0.01–0.20 g). Gross energy should be at least 3 000 cal/kg for grow-out and 3 400 cal/kg for beginner feeds. Other nutrients in formulated feed such as crude lipids, calcium, phosphorus, fibre, mineral, lysine and methionine and aflatoxin are also standardized. There are about 5–6 types of feeds that are produced for different stages of tiger shrimp. The nutrient composition of the various products does not differ much among producers. Table 12 is an example of the general nutrient composition of shrimp feeds.

Feed is distributed through an elaborate network of dealers and sub-dealers throughout the country. Each company sets up its own distribution channel to cover markets in coastal provinces from the south to the north of Viet Nam. The average price of grow-out feed is US$1.00 per kg and does not vary much among companies. Dealers typically provide the feed on a cash-only basis during the first two months of a crop, where after credit can be extended for the remaining culture period depending on growth and survival.

3.3 Fish feeds

Formulated pellets are used mainly in *Pangasius* catfish and red tilapia. However, trash fish still remains as one of the major feed components for all omnivorous and carnivorous fish species.

3.3.1 Trash fish

Trash fish is traditionally used to feed freshwater and marine carnivorous fish and lobsters. Trash fish mainly comprises low value species from the marine and inland capture fisheries. The rapid development of carnivorous fish culture has resulted in an imbalance between supply and demand and this has led to substantial price increases

TABLE 13
An estimation of trash fish used for inland and marine fish culture in Viet Nam

Species	Production (tonnes)	%of trash fish use	FCR	Moist/wet feed (tonnes)	Trash fish (tonnes)	
					Min	Max
Pangasius catfish	180 000	80	2.50	360 000	64 800	180 000
Marine shrimp	160 000	38	4.74	287 280	71 820	143 640
Marine fish	2 000	100	5.90	11 800	11 800	11 800
Lobster	1 000	100	28.00	28 000	28 000	28 000
Total				**6 870 801**	**176 420**	**363 440**

Source: Edwards, Tuan and Allan (2004)

in recent years. There are no official statistics on trash fish consumption by the aquaculture sector. However, Edwards, Tuan and Allan (2004) estimated (Table 13) that between 64 800–180 000 and 72 000–144 000 tonnes of trash fish is used for inland and coastal aquaculture, respectively and that total consumption of the aquaculture sector in Viet Nam was between 177 000–364 000 tonnes per annum.

It is likely that Edwards, Tuan and Allan (2004) underestimated trash fish consumption because they did not take full account of snakehead culture in the Mekong Delta. There have been many Research and Development (R&D) attempts to promote the use of alternative feeds for carnivores but results have not been widely applied in practice.

3.3.2 Pangasius *catfish feed*

Viet Nam is the largest producer of pangasiid catfish in the world. The national production in 2004 was about 260 000–300 000 tonnes (MOFI, 2004). Basa catfish (*P. bocourti*) and tra catfish (*P. hypophthalmus*) are the dominant culture species in Viet Nam. Besides farm-made feeds, formulated feeds are increasingly being used in catfish production. Although the cost of manufactured feeds is higher than that of farm-made feeds, farmers are of the opinion that the quality of fish is improved when manufactured feeds are used. Contrary to commercial shrimp feeds, catfish feeds are formulated using mostly local ingredients such as rice bran, cassava meal, soybean meal, local fishmeal and feed additives. All manufactured feeds are extruded. The leading catfish feed producers at present are Proconco, Cargill, Uni President and Green Feed. Collectively, these companies have an installed capacity of 80 000–100 000 tonnes per year (Table 14) (Hung, 2006).

Local companies such as Afiex, Cataco and Vinh Tuong also manufacture significant volumes of catfish feeds. Collectively, these companies have an installed capacity of 30 000–50 000 tonnes per year. There are no official data for commercial catfish feed production. However, based on catfish production data it is estimated that some 300 000–400 000 tonnes of commercial catfish feed was produced in 2004.

Manufactured catfish feeds also have to meet feed quality standards as assigned by the Ministry of Fisheries (28 TCN 188:2004, see Appendix A.2.), according to which the crude protein content in formulated feeds should be at least 18 percent for grow out (500 g) and up to 40 percent for fingerlings (1–5 g). Gross energy should be in the range of 1 500 cal/g for fish size of 500 g and up to 3 300 cal/g for fingerlings (1–5 g). Other nutrients including lipid, fibre, ash, calcium, phosphorus, lysine and methionine are also standardised. Table 15 is an example of the nutrient composition of a commercial catfish feed.

TABLE 14
Annual capacity of catfish feed producers

Feedmill	Location	Annual production capacity (tonnes)
Multinational		
Proconco	Can Tho	100 000–120 000
Cargill	Dong Nai	60 000–80 000
Uni President	Binh Duong	60 000–80 000
Green Feed	Long An	60 000–80 000
Woosung	Dong Nai	60 000–80 000
Tan Sanh	Mekong Delta	40 000–50 000
Local		
Viet Thang	Mekong Delta	40 000–50 000
Afiex	Mekong Delta	30 000–50 000
Cataco	Mekong Delta	30 000–50 000
My Tuong	Mekong Delta	20 000–30 000

Source: Hung (2006)

TABLE 15
Nutrient composition of a commercial formulated feed for *Pangasius* catfish (percent dry matter basis, unless otherwise indicated)

Feed types	Crude protein (minimum)	Crude lipid minimum	Calcium	Crude fibre	Phosphorus	Moisture	ME (cal/kg)	Lysine	Methionine
6106	35	3.0	1.0–3.0	6	0.95	11.0	2 500	1.50	0.85
6116	32	3.0	1.0–3.0	6	0.95	11.0	2 600	1.45	0.70
6326	28	2.5	1.0–3.1	6	1.00	11.0	2 000	1.30	0.65
6336	25	2.2	0.8–2.5	7	1.00	11.0	2 000	1.00	0.50
6346	22	2.2	0.8–2.5	7	1.00	11.0	2 000	0.80	0.45
6356	20	2.2	0.8–2.5	7	1.00	11.0	2 000	0.60	0.50

Source: Green Feed Company (pers. com.)

TABLE 16
Nutrient composition of commercially formulated tilapia feed (% dry matter basis)

Fish stage/size (g)	Feed type/Ssize (mm)	Moisture	Crude protein	Crude lipid	Crude fibre	Ash
Fingerlings	Crumbles	11	40	5	4	10
5–20	Pellet (1.5)	11	40	5	4	10
20–200	Pellet (2.0)	11	30	6	4	10
200–400	Pellet (3.0)	11	30	6	4	10
400–600	Pellet (5.0)	11	22	5	6	12
600–1000	Pellet (7.0)	11	22	5	6	12

Source: Cargill Company (pers. com.)

The average price of the feeds is around US$0.35/kg for starter feeds with 30 percent crude protein and US$0.25/kg for grower feeds (18–20 percent crude protein). Typical FCRs are around 1.5 and 2.0:1 in ponds and cages, respectively.

3.3.3 Tilapia feed

Because of the integrated nature of tilapia farming in Viet Nam the use of formulated feeds is unprofitable. Several previous attempts to culture GIFT (genetically modified farm tilapia) tilapia in cages using formulated feeds have not yielded good economic results, though recent work by the Research Institute for Aquaculture (RIA) No. 1 suggests otherwise. However, the use of formulated pellets for cage and tank farming of red tilapia is a viable proposition. In the past farmers simply used formulated catfish pellets, but because of increasing demand for a tilapia formulation, manufacturers have recently introduced a feed to the market. There is no official data for tilapia feed consumption but based on red tilapia production in Viet Nam, it is estimated that there would be a current demand of around 50 000–60 000 tonnes of tilapia feed per annum.

In 2004, MOFI published a quality standard for formulated tilapia feeds (28 TCN 189: 2004, Appendix A.3.). Crude protein content should be in the range of 20 percent for grow-out (500 g fish size) to 40 percent in crumble feeds for fingerlings (5 g). Gross energy should be at least 2700 cal/g for growth out and up to 3200 cal/g for fingerling feed. Other nutrients are also standardized. Table 16 provides an example of the nutrient composition of tilapia feeds.

3.3.4 Marine fish feed

Grouper, cobia, sea bream, snapper are currently the four main marine fish cultured in Viet Nam. As outlined above and mainly for economic reasons trash fish remains the feed of choice (Edwards, Tuan and Allan, 2004). Formulated feeds, imported from Taiwan Province of China are currently being tested to replace trash fish. Two feed companies (Uni President and CP Group) have attempted to develop a local formulation to replace trash fish in marine fish farming (Orachunwong , Thammasart and Lohawatanakul, 2005).

4. FERTILIZERS, FEED INGREDIENTS AND FEEDS IN AQUACULTURE

In semi-intensive and intensive fish farming systems, nutrient inputs including feeds and fertilizers are essential for fish production. This section of the review focuses on fertilizer use and supply and feed ingredient composition, availability and supply.

4.1 Fertilizers

4.1.1 Inorganic fertilizers

Viet Nam imports most of its inorganic fertilizers for rice farming and other crops and supply is rarely limited. However, the use of inorganic fertilizers has not yet become a common practice in aquaculture in Viet Nam. Fertilizers are mainly applied for intermediate stimulation of phytoplankton growth during the nursery period.

The most commonly used inorganic fertilizers are Urea, NPK and DAP (di-ammonium-phosphate).

Urea is the most popular fertilizer applied to shrimp ponds and is applied at a loading rate of 20–30 kg/5 000 m^2 to boost phytoplankton growth in the initial 15–20 days, during which the post larvae cannot feed on pelleted feed. The most common NPK formulation used is 18:46:0, while di-ammonium-phosphate (DAP) (40 percent P_2O_5 and 18 percent N) is employed in freshwater nursery ponds and intensive shrimp ponds to stimulate intermediate growth of algae and phytoplankton.

TABLE 17
Nutrient content of common animal manures used in aquaculture in Viet Nam

Manure	Percent (fresh weight basis)			
	Moisture	N	P_2O_5	K_2O
Pig	82.0	0.8	0.4	0.3
Cattle	83.1	0.3	0.2	1.0
Horse	75.7	0.4	0.4	0.4
Chicken	56.0	1.6	0.5	0.9
Duck	56.0	1.0	1.4	0.6

Source: Dat (2002)

TABLE 18
Composition of common green fodders used as fertilizers in Viet Nam

Plants	Percent (dry matter basis)	
	N	P_2O_5
Back bean	1.7	0.3
Water hyacinth	4.8	0.6
Duck weed	2.8	0.4

Source: Dat (2002)

4.1.2 Organic fertilizers

The types of organic fertilizer and application rates vary and are dependent on the system, species and farmer habits. Farmers apply various organic fertilizers for pond preparation and or during the nursing stage. Sewerage fed aquaculture systems, particularly for the rearing of red tilapia fry and fingerlings, are popular in Ho Chi Minh City and Ha Noi. However, there are various factors, such as the rapid rate of urbanization, land availability and consumer demands, that presently limit the use of sewerage as a fertilizer source.

Animal manures

As mentioned earlier, animal manures are frequently used in integrated systems to maximize the use of on-farm resources. Application rates are highly variable because farmers are generally not well informed. The general recommended application rate is 25–30 kg/100 m^2 as the primary nutrient base for the development of natural foods in polyculture ponds.

The nutrient content of different animal manures used in aquaculture are shown in Table 17. Chicken, pig and duck manures have the highest N and P_2O_5 content and hence are most frequently applied in aquaculture systems.

The direct application of manure to fish ponds is not a common practice in Viet Nam due to competition with crop farming. However, many farmers construct a pigsty or chicken house over the fishponds or in close proximity to their ponds. It has been found that 2–3 pigs are adequate to fertilize a fishpond area of 500–1 000 m^2.

Green fodder fertilizer

Besides animal manures, some green fodders are also composted to provide pond nutrients. Common green fodders that are used as fertilizers are listed in Table 18. The fodder is placed in a crib in the corner of a pond and the nutrients released stimulate natural productivity. This type of fertilization is usually practiced in small-ponds under polyculture conditions and is most commonly used in upland areas in the central highlands and in southeastern Viet Nam.

4.2 Feed Ingredients

4.2.1 Rice and rice by-products

The conversion rate of paddy rice into its by-products is 64 percent rice, 10 percent rice bran and 6 percent broken rice. The national yearly production of paddy is about 33–34 million tonnes (MARD). Rice and broken rice is mainly used for human

TABLE 19
Annual production of paddy, rice bran and broken rice during 1998-2002

Year	1998	1999	2000	2001	2002
	Production (million tonnes)				
Rice paddy	29.15	31.39	32.53	32.98	33.54
Rice bran	2.91	3.14	3.25	3.30	3.35
Broken rice	1.75	1.88	1.95	1.98	2.01

Source: Ministry of Agriculture and Rural Development, MARD (pers. com.)

TABLE 20
Estimation of rice bran use in aquafeeds for catfish (tonnes)

Feed types	Production	% rice bran		Rice bran used in aquafeeds	
		Min	Max	Min	Max
Formulated feeds	300 000	20	50	60 000	150 000
Farm-made feeds	500 000	40	70	200 000	350 000
Tilapia feeds	50 000	20	40	10 000	20 000
Total				**270 000**	**520 000**

consumption, while rice bran and a small proportion of broken rice are used for animal feed. These by-products are indispensable ingredients in formulated and farm-made feeds for tilapia and *pangasiid* catfish feeds but is rarely used in shrimp feed due to its high fibre content. In 2002, the annual production of rice bran and broken rice in Viet Nam was 3.3–3.5 million and 2.0–2.1 million tonnes, respectively (Table 19).

The inclusion rate of rice bran in formulated catfish and tilapia feeds varies from 20–50 percent, depending on the growth stage. In farm-made feeds, rice bran is used at inclusion rates of 40–70 percent (Phuong, Minh and Tuan, 2004). There are no official data of rice bran consumption by aquaculture. An estimation based on fish production, average FCRs and average inclusion rates is provided in Table 20. The data suggest that the aquafeed industry annually needs 300 000–500 000 tonnes of rice bran. According to the above estimate, domestic rice production can supply the demand of both the animal and aquafeed industries.

TABLE 21
Nutrient composition (% as fed basis) of rice bran and defatted rice bran in Viet Nam

Composition	Dry matter	Crude protein	Crude lipid	NFE	Ash	Crude fibre
Rice bran type I	87.6	13.0	12.0	46.4	8.4	7.8
Rice bran type II	90.3	9.8	6.8	40.1	15.1	18.6
Rice bran type III	89.7	7.6	5.0	38.9	14.9	23.3
Defatted rice bran	89.0	14.9	3.6	47.6	10.4	11.2

Source: NIAH (1995)

There are three types of rice bran in Viet Nam. Type II and III have a low protein content and are not suitable for extruded feeds due to a high fibre content (Table 21). However, they can be used for farm-made feeds. On-farm storage of rice bran is difficult because of the high lipid and moisture content and this affects feed quality. Feedmills usually dry and store large volumes in silos.

De-fatted rice bran (DRB) has a higher protein but lower lipid content than other brans and is therefore commonly used in animal feed.

4.2.2 Wheat flour and wheat bran

Viet Nam imports wheat flour and wheat by-products for human consumption as well as for the animal and aquafeed industries. Some 868 000 tonnes of wheat and by-products were imported in 2004. Shrimp feeds require about 10–15 percent of wheat flour as a binding agent and an energy source. Wheat gluten is also used in shrimp feed while wheat bran is incorporated into catfish feeds.

4.2.3 Maize and maize by-products

Maize and its by-products, including maize bran, maize gluten and maize starch are important components in animal feeds, especially for the poultry feed industry. Domestic maize production does not meet demand and the shortfall is imported. The inclusion rate of maize in aquafeeds varies depending on the kind of product. It can be as high as 35 percent for maize grain meal and 20 percent for maize bran in omnivorous fish feeds (Hertrampf and Pascual, 2000).

However, maize and maize by-products are seldom used in commercial and or farm-made aquafeeds in Viet Nam. The high astaxanthin and canthaxanthin content in maize meal and bran discolours the fish fillet in pangasiid and clariid catfish. Moreover, the higher price of maize meal and bran in comparison to broken rice and rice bran has restricted the use of maize products in aquafeeds.

4.2.4 Cassava and cassava meal

Cassava is not a staple food in Viet Nam. It is used mainly for animal feed and for industrial purposes. In 2003 Viet Nam produced some 5.23 million tonnes. There is no official data on cassava usage in animal feeds. Cassava root is a perishable food and has high moisture content (70 percent) at harvest. Cassava meal is a processed product by sun drying, chopping and grinding the root. Protein content is low (0.9 percent for root and 2.8 percent for meal) and starch content is high. In the central highlands, northeastern and southeastern Viet Nam farmers use fresh cassava root to feed common carp and grass carp in cages and in the Mekong Delta, farmers often use cassava root to feed freshwater prawns.

Cassava meal is used in the manufacture of extruded floating pellets and is included at up to 15 percent. Approximately 30 000–45 000 tonnes of cassava meal is used by the aquafeed industry annually. Cassava is not a common ingredient for traditional farm-made feeds.

4.2.5 Trash fish

Trash fish is that part of the by-catch of marine or inland capture fisheries that is not normally used for human consumption. Traditionally trash fish has been used as a feed for carnivorous as well as omnivorous fish. According to MOFI, trash fish production in 2002 was 200 000 tonnes, comprising 14 percent of total capture fisheries landings. However, Edwards, Tuan and Allan (2004) estimated trash fish production at approximately 0.93 million tonnes in 2001, suggesting that the MOFI underestimated the proportion of trash fish from the capture fisheries.

Trash fish is currently an indispensable feed for carnivorous fish and as mentioned above is also used in farm-made feeds for omnivorous species. Previously, trash fish was very abundant during the flood season in the Mekong Delta and was used for human consumption, manufacture of fish sauce and as a feed for snakehead. Snakehead culture in the Delta has developed to such an extent that farmers now have to use trash fish of marine origin. FCR of trash fish ranges from 4–5 for snakeheads and as high as 12–15:1 for grouper (Trai and Hambrey, 1998). Farm-made feeds contain between 20–30 percent of trash fish and Edwards, Tuan and Allan (2004) estimated that if only 50 percent of *Pangasius* farmers incorporate trash fish into their feeds then some 65 000–180 000 tonnes are used by these farmers alone.

The quality of trash fish is a major concern. Quality declines rapidly as only ice or chilled water is used to preserve trash fish at sea. This is compounded by inadequate on-board storage facilities as the vessels stay at sea for one to four weeks. Edwards, Tuan and Allan, (2004) estimated that between 50 and 60 percent of the total offshore trawler catch goes to waste because of poor storage.

The supply of marine trash fish is highly seasonal, causing major fluctuations in supply and price. During the high fishing season the price ranges between VND 1 500–2 000/kg and during the rough seas season (October to December) the price increases to VND 3 000–5 000/kg. Trash fish availability is considered one of the most serious constraints for aquaculture development in Viet Nam.

4.2.6 Live organisms

Small-scale farmers usually use various live organisms to feed their fish. Similar to other countries, termites, small frogs and golden snails are the most common feed

organisms. The most important of these for aquaculture is the golden snail that was introduced into Viet Nam in the 1980s for human consumption and in the hope of developing an export industry. The species has now become a catastrophic pest. With the shell removed the snail has a protein content of 9–11 percent, 0.3–0.7 percent lipids and 3.9–8.3 percent carbohydrate and is used particularly as an ingredient in freshwater prawn and fish feeds. The snails are minced and mixed with rice bran at a ratio of 10 parts snail and 1 part rice bran. Prawn FCRs with this mixed feed ranges from 10–15:1 (Hien, 2004). The price of snails (shell-removed) at VND 1 200–1 500/kg is often cheaper than trash fish at VND 2 500–3 000/kg.

4.2.7 Fish processing waste

Viet Nam has 600 fish processing factories that produce fish fillets, beheaded and shelled shrimp and process molluscs before freezing and packing. A large quantity of processing waste is consequently produced.

It has been estimated that some 30 percent of processed shrimp ends up as waste and that some 60 000–70 000 tonnes of shrimp head waste is produced annually. The product has a protein content of 33.5 percent, 3.5 percent lipids, 26.4 percent minerals (NIAH, 1995). Shrimp head waste is a good source of protein for fish feed but its digestibility is low. It can be used as a direct feed for hybrid clariid and pangasiid catfish or can be sun dried to produce shrimp head meal, which is an essential component in shrimp feed since it is rich in chitin, astaxanthin and attractants. The inclusion rate in shrimp feeds varies between 2–5 percent.

It has been estimated that pangasiid catfish processing waste amounts to around 210 000 tonnes per annum. The waste is processed into various products for human consumption and as well as for animal and fish feeds (particularly for pangasiid catfish). There is an urgent need to evaluate the potential of using a proportion of the waste for the production of fishmeal.

Mollusc processing factories also produce offal, which is sometimes used for the feeding of hybrid clariid and pangasiid catfish. Unfortunately none of the factories process mollusc waste into oil, squid liver meal and other mollusc meal and hence Viet Nam has to import these products for incorporation into shrimp feeds.

4.2.8 Fishmeal

Fishmeal is an essential component of most commercial aquafeeds. Viet Nam produces between 3 000 and 10 000 tonnes of fishmeal and 185 000 tonnes of "fish powder" per annum (Edwards, Tuan and Allan, 2004). Fish powder is made in the traditional manner (drying and grinding). Fishmeal is manufactured mainly form trash fish, spoiled fish and processing waste and hence is of inferior quality to the imported equivalent and sometimes contains high levels of histamine and cadaverine substances (Edwards, Tuan and Allan, 2004). The protein content (Table 22) of local fishmeal varies between 30 and 59.3 percent (NIAH, 1995). Local fishmeal is not used in shrimp feeds.

There are no official data of fishmeal consumption by aquaculture and this had to be estimated based on aquaculture production statistics and inclusion rates in various

TABLE 22
Proximal composition (percent dry matter basis) of fishmeal produced in Viet Nam

Fishmeal type	Crude protein	Crude lipid	Crude fibre	Ash	Ca	P
Fishmeal Ba Hon	57.6	1.0	0.7	15.8	5.2	2.7
Fishmeal Da Nang	45.0	12.0	2.4	29.6	5.0	2.5
Ha Long 45%	45.0	6.4	2.4	27.0	5.0	2.2
Ha Long 50%	50.0	4.3	-	25.1	5.0	2.5
Kien Giang	30.0	6.9	4.2	38.2	8.3	3.2
Fishmeal 60%	59.3	8.2	-	24.2	5.1	2.8

Source: NIAH (1995)

TABLE 23
Estimation of fishmeal use in aquafeeds in Viet Nam

Feed types	Production	% fishmeal		Fishmeal used in aquafeed	
		Min	Max	Min	Max
Shrimp feed	180 000	20	25	36 000	45 000
Catfish feed	300 000	3	5	9 000	15 000
Tilapia feed	50 000	3	5	1 500	2 500
Total				**46 500**	**62 500**

feeds (Table 23). The analysis suggest that some 45 000 to 60 000 tonnes of fishmeal were required for aquafeeds in 2003. This estimate is not much different to that of Edwards, Tuan and Allan (2004) who estimated that Viet Nam used a minimum of 30 000 to a maximum of 105 000 tonnes of fishmeal for aquafeeds in 2001/2. Given the production of local fishmeal suggest that at least 90 percent of fishmeal used in aquafeeds is imported. Fishmeal imports to Viet Nam have increased from 14 000 tonnes in 1999 to 60 000 tonnes in 2003. Edwards, Tuan and Allan (2004) predict that Viet Nam will require at least 150 000 to 200 000 tonnes of fishmeal per annum to sustain the current growth rate of aquaculture in the country.

The price of fishmeal in Viet Nam depends entirely on protein content. The current average price is VND 150 per percent of protein, such that fishmeal with 60 percent protein costs VND 9 000/kg, though high quality fishmeal from Chile or Peru costs around VND 10 000/kg (prices in May 2005; US$1.00 = VND15 900).

4.2.9 Fish oil

Apart from the small-scale production of oil from pangasiid catfish waste, Viet Nam does not produce fish oil and this commodity is imported from South Korea, Chile and Peru. About 2 000–3 000 tonnes of fish oil is currently used in the feed industry (Edwards, Tuan and Allan (2004). Fish oil is mainly used in formulated feed for tiger shrimp at an inclusion rate of 1–2 percent. In addition, shrimp farmers also use fish oil for top dressing of pelleted feeds because they perceive this to enhance shrimp feeding behaviour. Pangasiid oil is included into farm-made feeds at around 2–5 percent and is also used by some feedmills in *Pangasius* and tilapia feeds.

4.2.10 Soybean meal

Soybean meal is the primary protein component in most commercial animal feed formulations and is also the main protein component in formulated aquafeeds. In 2003 Viet Nam produced 225 300 tonnes of soybeans of which about two-thirds was consumed directly as food products (e.g. tofu, soymilk) with the balance going to animal feeds. The quality of local soybean meal is good (Table 24).

In 2003, Viet Nam's soybean meal imports were estimated at 960 000 tonnes, an increase of 27 percent over the 795 000 tonnes imported in 2002. Argentina and India were the key soybean meal suppliers to Viet Nam. In 2004, soybean meal imports increased by 14 percent over 2003 to 1.1 million tonnes (Huong, 2004).

Soybean meal inclusion rates in shrimp feeds range from 15–20 percent, for omnivorous species between 20–30 percent and for pangasiid catfish can be as high as 40–50 percent, without affecting fish growth (Hung, 2004). Because of the increasing scarcity of trash fish about 38 percent of farmers are now using soybean meal in their

TABLE 24
Nutrient content (percent as fed basis) of soybean meal produced in Viet Nam

Nutrient extract	Dry matter	Crude protein	Crude lipid	Crude fibre	NFE	Ash
Mechanically extracted	86.5	42.6	7.4	5.9	24.7	5.9
Solvent extracted	89.0	44.7	1.5	5.1	32.2	5.5

Source: NIAH (1995)

TABLE 25
Estimation of soybean meal use for aquafeed

Feed types	Production	% soybean meal		Soybean meal used in aquafeed	
		Min	Max	Min	Max
Shrimp feed	180 000	10	15	18 000	27 000
Catfish feed	300 000	20	30	60 000	90 000
Tilapia feed	50 000	20	30	10 000	15 000
Total				**88 000**	**132 000**

TABLE 26
Nutrient content of some common terrestrial and aquatic plants used as feeds or fertilizers in aquaculture

Green fodders	wet weight basis					
	Moisture	Crude protein	Crude lipid	Carbohydrate	Cellulose	Mineral
Duck weed	92.0	1.5	0.2	5.4	0.1	1.1
Water hyacinth	92.9	2.1	6.7	2.6	0.6	0.9
Water morning glory	91.6	1.9	0.8	-	1.4	1.1
Cassava leaf	73.4	5.2	3.5	-	5.0	1.8

Source: Bao Thang Company (2002) (pers. com.)

farm-made formulations. As for most other feedstuffs there are no official statistics of soybean meal use in aquafeed and this was estimated (Table 25) using the same rationale as for the other commodities. The data suggest that some 80 000–130 000 tonnes soybean meal is used in commercial and farm-made aquafeeds.

4.2.11 Other plant proteins
Substantial quantities of groundnut meal and coconut meal are produced in Viet Nam, but for various reasons are not used to any significant degree in farm-made and or commercial aquafeeds. Other oilseed cake meals such as rapeseed meal, palm kernel meal, cottonseed meal are imported for animal feed but not used in aquafeeds.

4.2.12 Green fodder
Green fodders are used as supplemental feeds for herbivorous fish such as grass carp, gourami and silver barb. The common green fodders and their nutrient content are presented in Table 26.

4.2.13 Premix and feed additives
In formulated feeds vitamin and mineral premixes and feed additives play an essential and important role in the enhancement of animal health and physiological function. There are several multinational and local companies in Viet Nam that produce premixes for animal feeds, of which DSM, Nutriway and Bayer are the leading producers. The inclusion rates are usually 0.025 percent for catfish and tilapia feed and 0.1–0.2 percent for shrimp feeds. Other feed additives such as ascorbic acid, lysine, methionine, anti-oxidants, anti mould agents, astaxanthin, feed attractants, feed stimulants, and probiotics are readily available in Viet Nam. All the ingredients for premixes are imported.

5. PROBLEMS AND CONSTRAINTS
The National Development Plan expects the aquaculture sector to produce 2 million tonnes by 2010. With a targeted annual growth rate of over 20 percent, many challenges are likely to arise. There are two ways to achieve the production target. Firstly by increasing the surface area for aquaculture and secondly by intensifying the existing aquaculture practices. Expanding water surface area for aquaculture can be relatively easily implemented in the central highlands, northeastern and northerwestern Viet Nam where population density is low, though these areas often lack adequate water

resources. Converting rice fields and other wetland agriculture ecosystems into fishponds has been an important step in the aquaculture expansion plan since the 1990's in the Mekong Delta and other places. Nevertheless, a continued switch from agricultural to aquaculture will limit rice and other crop production to ensure food security. Therefore, intensification of fish faming is obligatory for the sector to achieve its goals.

However, intensification requires more feeds and nutrient inputs. This may pose problems and constraints in terms of ingredient availability and accessibility and may also have socio-economic implications in respect of feed resource allocation as well as economic consequences for small and medium scale farmers.

5.1 Constraints in feed and feed ingredient availability and accessibility

5.1.1 Herbivorous fish

- *Grass availability, particularly in the dry seasons*: Herbivores, especially grass carp consume grass of up to 60–100 percent body weight per day. A 1000 m^2 fishpond used for culture of grass carp needs 1 to 2 labourers to collect sufficient volumes of grass. In some places, farmers have to travel up to 30 to 50 km to collect enough grass to meet the demand. There are not enough pastures reserved for feed and feeding of fish.
- *Supplemental and alternative feeds for grass carp and other herbivores:* In semi-intensive or intensive systems, grass is not adequate for grow-out and for decreasing the duration of the production cycle. More research is required to deal with the intensification of herbivorous fish culture.

5.1.2 Filter feeding fish

- *Manure availability and accessibility*: Integrated farming (e.g. VAC systems) is the most appropriate technology for small-scale farmers and is actively promoted. However, manure is not available and/or accessible in many places and farmers need to be educated on the value of applying manure to fish ponds.
- *Alternative nutrient inputs*: Inorganic (urea and DAP) fertilizers are readily available and accessible in Viet Nam. However, farmers are poorly educated in the use of inorganic fertilizers. There is a need for improved training and extension services.

5.1.3 Omnivorous fish

- *Trash fish shortage*: As indicated above the pangasiid catfish industry annually needs 60 000–180 000 tonnes trash fish and this will be doubled if catfish production reaches the target of 0.5 million tonnes in 2010. The supply of trash fish is the main limiting factor to achieving the above production target.
- *Fishmeal shortage*: Viet Nam is not capable of producing adequate volumes of fishmeal for the animal and aquaculture feed industries. The country therefore has to import most of its fishmeal requirements. Future world supply of fishmeal may constrain the development of the aquaculture sector in Viet Nam.
- *Alternative ingredients to fishmeal/trash fish*: Oilseed cake meals are good protein sources to partially replace fishmeal or trash fish in catfish and tilapia feeds. Feedmillers need to examine the use of alternatives such as sunflower oilseed cake and others. Soybean meal is readily available on international markets. Other local oilseed cake meals are available but the quality of these commodities has to be improved such that they can be used more effectively in aquafeeds. Small- and medium-scale farmers are constrained to a much greater extent in the search for alternatives than the feedmills.

5.1.4 Carnivorous fish

- *Trash fish shortage*: Trash fish is considered to be the most limiting factor in carnivorous fish culture. The development of marine fish and snakehead culture has placed enormous strain on supplies.
- *Trash fish seasonality*: Trash fish supply is becoming more unstable over time. Its high seasonal availability is a severe constraint for carnivore aquaculture.

5.1.5 Shrimp

- Shrimp culture in semi-intensive and intensive systems require large volumes of feeds and nutrients and will be severely constrained if availability and accessibility of feed ingredients become problematic. The two major constraints facing the sector are future fishmeal shortages and the high tax on premixes and imported animal feed ingredients.

5.2 Social and economic constraints

- *Traditional feeding practices*: The study by Hung, Truc and Huy (2007) clearly shows that farmers need to change their traditional feeding practices, which depend largely on trash fish, if they are to remain profitable.
- *Access to credit:* A recent study by Thi (2005) showed that 83 percent of fish farmers in An Giang province face credit constraints. It may not be wrong to assume that most small- and medium-scale farmers in other areas face similar problems in finding adequate credit to buy feed ingredients and nutrients. Those that have access to banks may obtain a loan at a monthly interest rate of one percent. Those that do no have access to the formal banking sector have to take "hot loans" with monthly interest rates of 5–6 percent.

5.3 Farm-made feeds

Farm-made feeds are traditionally used on small and medium-scale farms. The intensification of aquaculture and reduced availability of trash fish and fishmeal will place severe constraints on the preparation of farm-made feeds by these farmers.

- Farm-made feeds for pangasiid catfish, marine carnivorous fish, lobsters, freshwater prawns, snakeheads are traditionally composed of trash fish and rice bran and other ingredients. The availability of trash fish is highly seasonal, hence the preparation of farm-made feeds using alternatives such as fishmeal and soybean meal are promoted but the practice is constrained by farmer habits. Commercial feed mills know how to compensate for nutrient deficiencies such as lysine and methionine but farmers do not. Farmers need to be trained in the use of alternatives such as soybean meal and this could be achieved through closer liaison between farmer associations and ingredient distributing companies.
- Although aquafeed ingredients are locally available, small-scale aquaculture farmers do not have adequate and ready access to good quality ingredients.
- Due to lack of knowledge farmers do not pay enough attention to storing their feed ingredients in an appropriate manner to prevent oxidation. Hence they have little understanding of feed quality and its effect on production and fish health.
- The high seasonal abundance of golden snails is a constraint for small- and medium-scale freshwater prawn farmers.
- Preparation of farm-made feeds for tiger shrimp is not a simple task. Several attempts have been made to train farmers in pellet production using local ingredients such as rice bran, wheat flour and trash fish. However, all attempts have failed because of high pond pollution levels caused by poor feed quality. It is not surprising that farmers have not adopted the procedures.

5.4 Commercially formulated feeds

The rapid advances and growth in the aquafeed industry for catfish and shrimp feeds poses several constraints.

- Commercially formulated feeds are expensive and feed cost amounts to 70–80 percent of total production costs in intensive systems. Shrimp farmers can accept the high feed prices since the benefits of higher survival compensates for the higher price. However, catfish cage farmers are severely constrained by the price of commercial feeds and are essentially forced to continue using trash fish based feeds. In the less traditional catfish farming areas in the Mekong Delta farmers are now growing catfish in ponds, in which FCRs using formulated feeds is better than in cages (see Hung, Truc and Huy, 2007). Similarly, only red tilapia cage farmers who are in close proximity to urban markets can justify the use of formulated pellets. Moreover, there is a traditional perception that farm-made feeds, using trash fish as the principal component, are superior to commercial feeds (see Hung, Truc and Huy, 2007).

6. RECOMMENDATIONS

- For the feeding for herbivorous fish the use of locally available agriculture by-products is highly recommended to maximise the use of local sources of protein in resource-poor and in remote areas. Development agencies must appreciate this and develop appropriate trials and demonstrations to establish these techniques.
- The use of VAC systems must be promoted for the farming of omnivores and filter feeders to maximise the use of on-farm resources.
- To maximize land use and increase fish yield greater use should be made of commercial feeds and the use of alternative ingredients for farm-made feeds. The replacement of trash fish by plant proteins, such as soybean meal, should be the first priority and farmers need to be trained in formulating plant protein based feeds.
- The feed industry in association with government agencies and universities must pay greater attention to the nutritional requirements of pangasiid catfish, such that diet formulation is optimised and least cost feeds can be produced.
- The high feed cost in Viet Nam makes the country's shrimp and catfish producers uncompetitive. The main reason for the high feed prices is the high import duty and tax on feed additives and imported animal feed ingredients. This must to be addressed by the appropriate authorities.
- The massive use of fresh trash fish is a major constraint to snakehead farming. Research on the use of pelleted feeds for carnivores such as snakehead and grouper has to be given priority. In this regard, better use must be made of fish processing by-products. Further studies are also needed to promote the wise use of agricultural by-products for fish farming. In particular the research should focus on trash fish replacement.
- Government should develop enabling policies and conditions that will lead to a reduction in feed prices. This will lead to greater international competitiveness for the export of fish fillets and shrimp.
- A database on the nutritional requirements of *Pangasius* catfish must be developed that may serve as a reference for the formulation of commercial and farm-made feeds. Investigations on the use of low value cultured fish to feed carnivorous fish should also be carried out.
- The knowledge base of extension workers on aquaculture nutrition and feeding must be enhanced such that farmers can intensify their activities.
- The Ministry of Fisheries must develop improved fisheries management regulations that prevent over exploitation of trash fish.

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APPENDIX
QUALITY NORMS, FEED STANDARDS, FEED SPECIFICATIONS AND FEEDING GUIDELINES OF AQUAFEEDS IN VIET NAM

A.1. Quality standard (28TCN 102: 2004) for formulated shrimp (*Penaeus monodon*) feeds

Feed type	Shape of feed	Size of shrimp (g)
1	Crumbles	0.01–0.2
2	Crumbles	0.2–1.0
3	Crumbles or pellet	1.0–5.0
4	Pellet	5.0–10.0
5	Pellet	10.0–20.0
6	Pellet	>20.0

A.2. Physical, chemical, micro-organism and veterinary hygiene safety standard for formulated shrimp (*Penaeus monodon*) feeds

Standard		Feed type					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1	Diameter of pellet (mm) not bigger	0.6	0.8	1.2	1.8	2.2	2.5
	Length/diameter ratio	1.5–2.5					
2	Broken rate (% weight) not higher	2					
3	Durability not lower (hours)	1					
4	Crude energy (kcal/kg feed) not lower	3 400	3 400	3 200	3 200	3 000	3 000
5	Moisture (% weight) not higher	11					
6	Crude protein (% weight) not higher	42	40	39	38	37	35
7	Crude lipid (% weight)	6–8	6–8	5–7	5–7	4–6	4–6
8	Crude fibre (% weight) not higher	3	3	4	4	5	5
9	Ash (% weight) not higher	14	14	15	15	16	16
10	Sand (ash un-dissolvable in HCl 10%) (% weight) not higher	1	1	2	2	2	2
11	Calcium (% weight) not higher	2.3					
12	Calcium/phosphorus ratio	1.0–1.5					
13	NaCl (% weight) not higher	2.5					
14	Lysine (% weight) not lower	2.1	2.1	1.8	1.8	1.7	1.7
15	Methionine (% weight) not lower	0.9	0.9	0.8	0.8	0.7	0.7
16	Alive insects	Not permitted					
17	Pathogenic bacterium (*Salmonella*)	Not permitted					
18	*Aspergillus*	Not permitted					
19	*Aflatoxin*	<10 ppb					
20	Antibiotic and chemical is not allowed to be used by Resolution No. 01/2002/QD-BTS, January 22, 2002 of Ministry of Fisheries, Viet Nam	Not permitted					

A.3. Quality standard (28TCN 188: 2004) of formulated feed for pangasius catfish (*Pangasius* sp.)

Feed type	Shape of feed	Size of shrimp (g)
1	Crumble or pellet	<1
2	Crumble or pellet	1–5
3	Pellet	5–20
4	Pellet	20–200
5	Pellet	200–500
6	Pellet	>500

A.4. Physical, chemical, micro-organism and veterinary hygiene safety standard for formulated catfish feed

Standard		Feed type					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1	Diameter of pellet (mm) not bigger	1	1.5	2.5	5	10	12
	Length/diameter ratio	1–1.5					
2	Broken rate (% weight) not higher	2					
3	Durability not lower (hours)	30					
4	Crude energy (kcal/kg feed) not lower	3 300	2 800	2 400	2 100	1 800	1 500
5	Moisture (% weight) not higher	11					
6	Crude protein (% weight) not higher	40	35	30	26	22	18
7	Crude lipid (% weight)	8	6	5	5	4	3
8	Crude fibre (% weight) not higher	6	6	7	7	8	8
9	Ash (% weight) not higher	16	14	12	10	10	10
10	Sand (ash un-dissolvable in HCl 10%) (% weight) not higher	2					
11	Phosphorus (% weight) is not higher	1					
12	NaCl (% weight) not higher	2.5					
13	Lysine (% weight) not lower	2.0	1.8	1.5	1.3	1.1	0.9
14	Methionine (% weight) not lower	0.9	0.8	0.7	0.6	0.5	0.4
15	Alive insects	Not permitted					
16	Pathogenic bacterium (*Salmonella*)	Not permitted					
17	*Aspergillus*	Not permitted					
18	*Aflatoxin*	<10 ppb					
19	Antibiotic and chemical is not allowed to be used by Resolution No. 01/2002/QD-BTS, January 22, 2002 of Ministry of Fisheries, Viet Nam	Not permitted					

A.5. quality standard (28 TCN 189: 2004) of formulated feed for tilapia (*Oreochromis* sp.)

Feed type	Shape of feed	Size of fish (g)
1	Crumble or pellet	5
2	Pellet	5–10
3	Pellet	10–20
4	Pellet	20–200
5	Pellet	200–500
6	Pellet	>500

A.6. Physical, chemical, micro-organism and veterinary hygiene safety standard of formulated feed for tilapia (*Oreochromis* sp.)

Standard		Feed type					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1	Diameter of pellet (mm) not bigger	1.0	1.5	2.0	4.0	4.0	6.0
	Length/diameter ratio	1.0–1.5					
2	Broken rate (% weight) not higher	2					
3	Durability not lower (hours)	30					
4	Crude energy (kcal/kg feed) not lower	3 200	3 000	2 860	2 800	2 750	2 700
5	Moisture (% weight) not higher	11					
6	Crude protein (% weight) not higher	40	35	30	27	25	20
7	Crude lipid (% weight)	6	6	5	5	4	4
8	Crude fibre (% weight) not higher	5	5	6	6	7	7
9	Ash (% weight) not higher	19					
10	Sand (ash un-dissolvable in HCl 10%) (% weight) not higher	1	1	2	2	2	2
11	Calcium (% weight) not higher	2.5					
12	Calcium/phosphorus ratio	1.0–1.5					
13	NaCl (% weight) not higher	2.5					
14	Lysine (% weight) not lower	1.7	1.6	1.4	1.3	1.1	0.9
15	Methionine (% weight) not lower	1.0	0.9	0.8	0.7	0.6	0.5
16	Alive insects	Not permitted					
17	Pathogenic bacterium (*Salmonella*)	Not permitted					
18	*Aspergillus*	Not permitted					
19	*Aflatoxin*	<10 ppb					
20	Antibiotic and chemical is not allowed to be used by Resolution No. 01/2002/QD-BTS, January 22, 2002 of Ministry of Fisheries, Viet Nam	Not permitted					

A.7. Feed specifications and feeding guidelines for catfish and tilapia

Brand name/number	Feed size (mm)	Crude protein min. (%)	Fish weight (g)	Feeding rate (% body weight)	Feeding frequency (time/day)
Tilapia and catfish fingerling					
Aquaxcel-7404	<1.0	42	<1.0	15	>10
Aquaxcel-7414	1.0	40	1–2	10	>5
Aquaxcel-7424	1.2	40	2–5	10	>5
Aquaxcel-7434	1.5	35	5–20	5–10	>5
Aquaxcel-7444	1.5	35	>20	5–10	>5
Catfish grow-out					
7644	1.8	28	20–300	>5	5
7654	3.0	26	30–300	3–5	4
7664	3.0	22	300–500	2–3	3–4
7674	4.5	25	200–500	2–3	3–4
7684	4.5–6.0	22	>500	2–3	3–4
7694 NC	6.0	22	>500	2–3	3–4
7694 ND	10.0	22	>500	1–2	3
Tilapia grow-out					
	3	28	200–500	2–3	4
	4.5	25	>500	2–3	3–4
	4.5	25	>500	2–3	3–4

Source: Cargill Company (pers. com.)

A.8. Feed specifications, proximate composition and feeding guidelines for shrimp

Brand name	Feed type (mm)	Crude protein (minimum %)	Crude lipid (minimum %)	Mineral (maximum %)	Crude fibre (maximum %)	Calcium (minimum %)	Phosphorus (minimum %)	Shrimp size (g)	Age (days)	Feeding rate (% body weight)	Feeding frequency (time/day)	Quantity of feed for 100 000 shrimp (kg/day)
TB1	Powder	42	6	16	3	3.5	1.5	<0.2	1–10	12–10	2–4	0.24–1.6
TB2	Crumble	42	6	16	3	3.5	1.5	1–3	18–28	8–7	2–4	8–18
TB3	Crumble	42	6	16	3	3.5	1.5	1–3	18–28	8–7	2–4	8–18
TBS1	Pellet 1.8x2-4	42	6	16	3	3.5	1.5	3–6	25–50	7–5	3–4	18–28
TBS2	Pellet 2.0x3-5	40	6	16	3	3.5	1.5	6–10	40–63	5–4	3–4	28–33
TBG1	Pellet 2.2x3-4	38	6	16	3	3.5	1.5	10–15	60–82	4–3	4–5	33–49
TBG2	Pellet 2.2x4-5	38	6	16	3	3.5	1.5	15–21	77–106	4–3	4–5	49–60
TBF	Pellet 2.2x5-7	36	6	16	3	3.5	1.5	> 20g	100–120	3–2	5–6	60–76

Source: Tomboy Company (pers. com.)