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A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam

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Preface

Aquaculture is an important, and rapidly expanding, industry in Vietnam. While the demand for fish in South and Southeast Asia is increasing, production from capture fisheries is static or declining, and aquaculture will need to fill the gap.

One of the main constraints on increasing aquaculture production is the development of cost-effective feeds and feeding strategies.

The preferred protein source in most aquaculture is fishmeal or 'trash fish' (small fish forming the low-value component of commercial catches). However, supplies of trash fish are declining and prices are increasing. There is also an increasing conflict between the use of trash fish/fishmeal for aquaculture and for human consumption. The replacement of fishmeal in aquaculture diets is a major international research priority.

ACIAR supports projects investigating the use of alternatives to trash fish for aquaculture. This survey provides a snapshot of the industry in Vietnam by describing the production of trash fish, its usage and trends. The results will help determine how the future availability or price of trash fish will affect the development of aquaculture in Vietnam.



Peter Core

Director

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Glossary

ALMRV	Assessment of Living Marine Resources in Vietnam
DHA	Docosahexaenoic acid
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FCR	Food conversion ratio
ICLARM	The International Center for Living Aquatic Resources Management
MOFI	Ministry of Fisheries
MSY	Maximum sustainable yield
RIA	Research Institute for Aquaculture
RIMF	Research Institute for Marine Fisheries
SEAFDEC	Southeast Asian Fisheries Development Center
t	tonnes
VND	Vietnamese Dong

1. Executive summary

There is concern that in the future the rapid expansion of aquaculture may be constrained by increasing dependence on low-value marine “trash fish” and fish meal. From a reported aquaculture production of 0.65 million tonnes in 1999, the Vietnamese government is planning for production to double to 1.15 million tonnes by 2006 and triple to 2 million tonnes by 2010. It was thus timely to describe the production, uses (including alternatives) and trends of trash fish, fish meal and fish oil in Vietnam to assess if the availability of trash fish will restrict future expansion of aquaculture in the country. Field visits and interviews were carried out in Hai Phong, Khanh Hoa, Baria-Vung Tau, An Giang and Kien Giang provinces as well as in Hanoi and Ho Chi Minh City from 9–26 February, 2003 (Figure 1).

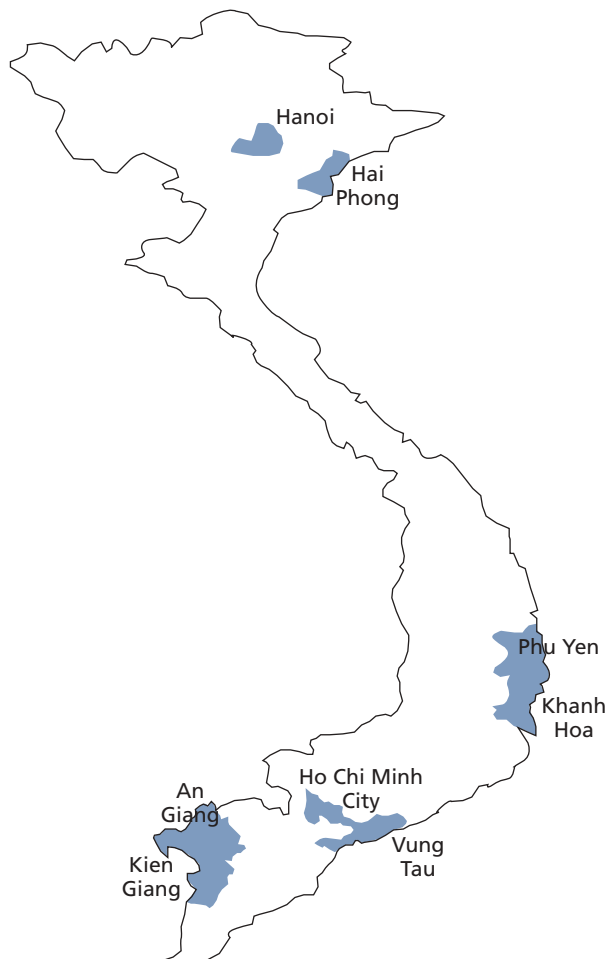


Figure 1. Map of Vietnam showing provinces visited.

There are conflicting data on the volume of trash fish landed. The inshore fishery in Vietnam is heavily over-fished but the total fish catch, as well as the proportion of biomass of trash in the total catch, continue to rise. There has been a dramatic rise in the use of trash fish in aquaculture with a probable doubling of its price, indicating a finite supply. It is unlikely that aquaculture based on traditional use of trash fish as a direct feed can expand considerably.

There are two types of fish meal in Vietnam: “fish powder” produced in a traditional artisanal way by sun-drying and grinding; and fish meal product using an industrial process in which raw materials are cooked before being dried. Fish powder is mainly used to feed livestock. Feed mills in Vietnam only use domestically produced fish meal for livestock and some freshwater fish for grow-out feed as it is generally of poor quality. Fish meal for higher quality feed for fish fingerlings and crustaceans is imported and represents about 90% of the total fish meal used. Fish oil for aqua feed manufacture is also imported. Future demand for fish meal is expected to increase dramatically as aquaculture production increases and some species, such as catfish, are increasingly fed pelleted diets containing fish meal. While high market value species such as grouper, lobster and shrimp may be able to compete for fish meal on the local market, catfish and tilapia will need to be fed increasing amounts of plant-based proteins.

2. Main findings in relation to Terms of Reference

Production, uses and trends of trash fish in Vietnam

There are conflicting data on the total marine fish catch in Vietnam, let alone for the volume of trash fish landed for which there are no official data. The total marine fish catch was estimated at 1.4 million t by MOFI (Ministry of Fisheries) compared with a generally agreed production of between 2–3 million t by local and international fisheries specialists. RIMF (Research Institute for Marine Fisheries) has estimated the total marine fish catch at 2.6 million metric t for the year 2001 (Table 1). According to RIME, there was a total of 0.93 million t of trash fish produced in 2001, that is, 36% of the total fish production, with the following percentages of trash fish by region: north (4.5%), middle (4.0%), southeast (66.3%) and southwest (25.1%). Thus, there is much more trash fish in south Vietnam than north Vietnam with the southeast region (Gulf of Thailand) producing almost two thirds of the total. There is relatively little trash fish landed in central Vietnam because mainly selective fishing gears are used in deeper water.

Table 1. Trash fish production by region in Vietnam in 2001.

Region	Total fishery (t)	Trash fish (t)	Trash fish Value (million VND)
The north	303,152.3	42,173.6	73,166.0
The middle	833,243.6	37,496.9	82,916.1
The southeast	987,184.6	619,063.2	900,997.9
The southwest	433,989.5	234,448.9	333,335.9
Total	2,557,570.0	933,182.6	1,390,415.8

Source: Tables to the report 'Preliminary Analysis of the Enumerator Sampling Program', RIME, Hai Phong, 2002.

There are over 100 species of marine "trash fish" that are used as an aquaculture feed or aquaculture feed ingredient in Vietnam. The major ones are listed in Table 2. Fish comprise the greatest amount but trash fish includes small molluscs, crustaceans and echinoids. The composition of trash fish will also vary depending on the type of gear used to fish but most is from trawling, hence one of the common names in Vietnamese for trash fish, "trawling fish". Composition also varies by area or region. The major trash fish species by area are anchovy (*Stolephorus* spp.) in the centre and southwest, lizard fish (*Saurida* spp.) in the north, centre and southeast and pony fish (*Leistognathus* spp.) in the centre and southwest. The relative abundance of trash fish is also highly seasonal (Appendix 3, Table 8). Trash fish, therefore, comprises mainly demersal species but pelagics may be used when fish landings exceed local marketing or fish processing capacity. Spoiled higher value species may also be used as trash fish.

In general there is no special fishery for trash fish. Trash fish is therefore a by-product of fishing for higher value fish, crustaceans and molluscs. The single exception was a report on the recent establishment of a fishing fleet at Cat Lo near Vung Tau in southeast Vietnam, where trash fish is the main target as it is more economic than fishing for larger species. Fish catches are sorted on board ship into high value species, mixed lower value species, and trash fish and are stored on ice in the hold. The more valuable species are unloaded first at the landing port and trash fish are unloaded last. Small mixed species are manually separated on the floor of the landing port, with the removal of more trash fish. The quality of trash fish is usually poor because of inadequate preservation on board ship, especially from offshore fisheries when vessels may be at sea for 1–6 weeks.

Table 2. Species comprising marine “trash fish” used as an aquaculture feed or aquaculture feed ingredient in Vietnam.

Scientific name	English name	Vietnamese name	Location
Mollusca	Mollusc	Nhuyen the	
<i>Hyriopsis cumingii</i>	Fresh water oyster	Trai nuoc ngot	C
<i>Sanguinolaris diphos</i>	?	Phi	C
<i>Ostrea</i> sp	Oyster	Hau	C
<i>Pteria martensii</i>	Penguin wing oyster	So giay	C
<i>Bilaglobosa swatson</i>	Golden snail	Oc vang	C
<i>Pila polita</i>	Apple snail	Oc buou	C
<i>Loligo</i> spp	Squid (small size, gut)	Muc (nho, ruot)	SW
Crustacea	Crustacean	Giap xac	
Penaeidea	Penaeid shrimp (small)	Tom nho	N, C
<i>Calappa</i> sp	Crab (small)	Cua nho	N, C, SW
<i>Portunus</i> spp	Swimming crab (small)	Ghe nho	N, C, SW
Echinodermata	Echinoderms	Da gai	
<i>Holodeima</i> spp	Lolly fish	Hai sam	C
<i>Holothuria vagabunda</i>	Black sea cucumber	Hai sam den	C
<i>Diadema setosum</i>	Black sea urchin	Cau gai den	C
	Marine fishes	Ca bien	
Rajiformes	Order Rajiformes	Bo ca duoi	
<i>Dasyatis</i> spp	Sting ray (gut)	Duoi (ruot)	SW
Clupeiformes	Order clupeiformes	Bo ca trich	
<i>Stolephorus</i> spp	Anchovy	Com	C, SW
<i>Clupea leiogaster</i>	Sardine	Trich	SW
<i>Thrissa mystax</i>	Moustached thryssa	Lep	C
<i>Clupanodon</i> spp	Gizzard shad	Moi	SW
Scopeliformes	Order Scopeliformes	Bo ca den	
<i>Saurida</i> spp	Lizard fish	Moi	N, C, SE
Anguilliformes	Order Anguilliformes	Bo ca chinh	
<i>Muraenesox cinereus</i>	Silver conger eel	Lat	C
Beloniformes	Order Beloniformes	Bo ca kim	
<i>Hemirhamphus far</i>	Half break	Kim bong	N, C
<i>Cyselurus</i> spp	Flying fish	Chuon	C, SW
Mugiliformes	Order Mugiliformes	Bo ca doi	
<i>Shyraena jello</i>	Giant sea pike	Nhong	SW
Perciformes	Order Perciformes	Bo ca vuoc	
<i>Otholithes argentius</i>	Croaker	Op	N
<i>Johnius goma</i>	Croaker	Uop	N, C, SW
<i>Upeneus</i> spp	Goat fish	Phen	N, SE
<i>Siganus</i> spp	Rabbitfish	Dia	N
<i>Decapterus</i> spp	Scad	Nuc	N, C, SW
<i>Scomber</i> spp	Mackerel	Bac ma	SW
<i>Rastrelliger brachisoma</i>	Short-body mackerel	Ba thu	SW
<i>Selaroides leptolepis</i>	Yellow-stripe trevally	Chi	SW
<i>Fonio niger</i>	Black pomfret	Chim den (nho)	SW
<i>Psenes indicus</i>	Indian pomfret	Chim An Do	C
<i>Priacanthus macracanthus</i>	Red bigeye	Son thoc	SE
<i>Leiognathus</i> spp	Pony fish	Liet	C, SW

<i>Nemipterus hexodon</i>	Ornate threadfin bream	Dong	SE
<i>Pomadasy s</i> pp	Grunter	Sao	C
<i>Platycephalus indicus</i>	Flathead fish	Chai	N, SW
<i>Tilapia</i> spp	Tilapia (small size)	Ro phi nho	C
<i>Pleuronectiformes</i>	Order Pleuronectiformes	Bo ca bon	
<i>Paralichthys olivaceus</i>	Flatfish	Bon vi	N
<i>Cynoglossus bilineatus</i>	Flounder	Bon cat	C
<i>Tetradontiformes</i>	Order Tetradontiformes	Bo ca noc	
	Leather jacket	Bo da	N, SE
	Unknown fishes*	Ca khac	
	By-products (head, gut) from processing (for drying) of fishes:	Phe pham (dau, ruot) tu che bien (phoi kho) cac loai ca:	
	Trevally, bream, lizardfish, ray, anchovy	chi, dong, moi, duoi, com	SW
	Lizardfish, Red bigeye, ray, pomfret	moi, thoc, duoi, chim	SE

N — the north; C — the centre; SW — the southwest; SE — the southeast.

* Also the following species for which only the Vietnamese name could be found: dao, nhit, nham, duoi, bem bep, khoai from the north; suot, chet from the centre; and bi from the southeast of Vietnam.

There is a consensus that the inshore fishery in Vietnam is heavily over-fished as there has been a tremendous increase in fishing effort, both in number and size of boats, since market liberalisation (doi moi) in 1984. The total fish catch continues to rise, as does the proportion of the biomass of trash fish in the total catch, that is, the composition of the catch is changing. Trash fish used to comprise only 30–40% of the catch from trawling but has risen to 50–60%, and even up to 80% in Kien Giang in the southwest region according to provincial records. Furthermore, fishing boats need to fish at increasing distances and for longer periods of time. Over-fishing has reduced the grazing pressure on trash fish by larger predatory fish. The relationships between the increasing degradation of inshore fisheries and the increasing supplies of trash fish are unclear but are being researched by RIMF.

The Government of Vietnam (GoV) is promoting offshore fisheries. One reason given is to take the pressure off inshore fisheries but there is no direct link between them. It is also debatable if significant offshore fish stocks exist, and there is the possibility of increased fishing pressure from offshore vessels that may move into inshore waters to catch fish. As fuel prices continue to rise faster than fish prices, fishers are finding themselves in a price squeeze. It was reported that, because of economics, the number of fishing vessels supplying trash for lobster culture in Van Ninh district fell in the areas of Khanh Hoa province.

According to MOFI, 25% of the national marine catch is used to feed animals (livestock and fish) and make fish meal, although this is likely to be an underestimate. However, there has been a dramatic recent rise in the use of trash fish in aquaculture with the development of marine cage culture of grouper and lobster, and the expansion of *Pangasius* sp. culture in cages, ponds and, more recently, pens.

There are no official data on the use of trash fish in the aquaculture industry in Vietnam although an estimate can be made from the farmed production of species fed trash fish. Estimates of trash fish used for inland and coastal aquaculture ranged from 64,800 t to 180,000 t and 71,820 to 143,640 t respectively. The total amount of trash fish used for aquaculture in Vietnam was estimated to be between 176,420 and 323,440 t.

The price of trash fish has risen over the last 3–5 years. The main reason for this is probably because of increasing demand for trash fish for feeding fish and livestock. Price varies depending on location and season but seems to have doubled recently. Prices of trash fish used to feed fish ranged from VND 1000–3000/kg but from VND 3000–6000 for anchovy to feed grouper and lobster in Khanh Hoa province. Future expansion of aquaculture using local supplies of trash fish is likely to be constrained with grouper farmers already reporting that they could not afford to buy it when the price rose. It appears that farmers raising higher value lobster could still afford to purchase relatively expensive trash fish. However, most farmers interviewed expressed concern about future supplies and cost of trash fish.

No trash fish are currently imported into Vietnam, although in the past small freshwater fish from Cambodia were imported to the Mekong delta. About 8000 t of trash fish are exported annually from north Vietnam, mainly Cat Ba, to China. Some shrimp peeling waste is sun-dried and exported to China for chitosan/chitin production.

There are competing uses for trash fish for livestock feed, fish sauce and direct human food, as well as for aquaculture feed and fish meal. Another common name for trash fish is “pig fish” as it is used in traditional small-scale pig rearing at the household level. However, large-scale pig farming uses formulated feed and competes for fish meal. The species defined as trash fish are also changing as some species previously considered to be trash fish are now being used as human food fish because of advances in processing technology. An example is leatherjacket, a bony fish that was rarely eaten in the past but can now be deboned and sun-dried for export.

Usage of trash fish depends very much on location. In Phu Quoc island in Kien Giang province and Phan Thiet in Binh Thuan province most of the trash fish is used for fish sauce manufacture. However, some trash fish landed at Phan Thiet is sun-dried as human food and is marketed in mountainous inland areas. In the two locations mentioned above there is no cage culture.

Small-scale manufacture of fish sauce is a traditional practice throughout coastal Vietnam, with the best quality sauce made from anchovy. In Binh Tan commune in Nha Trang, it was explained that Grade 1 anchovy costing VND 7000–10,000/kg was steam-dried and used in rice soup locally and exported; Grade 2 costing VND 4000–5000/kg was used for grouper and lobster culture; and Grade 3 costing VND 1000–4000/kg was mainly used for fish sauce manufacture. Although the production of fish sauce had increased in the commune by a factor of 15 over the past 10 years, there was no competition with aquaculture as the latter required better quality fish.

In contrast, the fish sauce factory visited in Kien Giang province had recently stopped using mixed trash fish because its price had risen due to increased demand for feeding *Pangasius* sp. in An Giang province. They now used more expensive anchovy to make a higher quality fish sauce, which was more profitable. Clearly the increasing use of low-value mixed trash fish for *Pangasius* culture is in direct competition with the production of low-cost fish sauce, which is important for the poor and overall national food security.

The availability of trash fish as a direct feed is likely to restrict the future expansion of aquaculture although the extent is both species and area specific. Supplies of trash fish are finite as indicated by a recent doubling of price. Thus, it is unlikely that aquaculture based on traditional use of trash fish as a direct feed can expand to the extent forecast in the Master Plan for aquaculture development. As the national demand for fish sauce is predicted to double over the next 10 years, there appears to be direct competition for mixed trash fish to feed *Pangasius* and to make low-cost fish sauce. However, aquaculturists of high value marine finfish and lobsters can afford to pay more for anchovy than fish sauce manufacturers in central Vietnam.

Novel culture of trash fish was observed in two eutrophic brackish water lagoons in peri-urban Nha Trang where Mozambique tilapia are grown for feeding grouper. A grouper farmer in Vung Tau indicated that he would try to culture tilapia as a trash fish in septage fertilised ponds. However, such a practice could not be expected to contribute much to the national trash fish supply because of land limitation and possible social aversion to wastewater reuse, even for feed production. Other sources of animal feed were also being used, for example, golden snails from rice fields. While lobster can consume the snail whole, labour intensive shucking would be required to feed grouper with snail meat.

Production, uses and trends of fish meal and fish oil in Vietnam

There are two types of fish meal in Vietnam, “fish powder” produced in a traditional artisanal way by sun-drying and grinding and an industrial process in which the raw materials are cooked before being dried. Fish powder is mainly used to feed livestock. Feed mills in Vietnam typically use domestically produced fish meal for livestock feed and some freshwater grow-out feed. As it has a low protein content it is not used to manufacture feed for fish fingerlings or crustacean. Fish meal for these species must be imported.

Total production of fish powder was estimated to be about 185,000 t and industrially produced fish meal of about 80,000 t with a capacity of 100,000–130,000 t. There were estimated to be 15–20 fish meal plants in operation although some may not use an industrial processing technology. The first industrial fish meal plant was opened by Kisimex in Kien Giang province in 1990. Most of the fish meal plants are in the south with only two active plants in the north and one or two in the centre of the country (Table 3). Most of the plants are in the south where the supply of trash fish is the greatest.

Table 3. List of fish meal plants in Vietnam.

Company/plant name	Location	Notes
Hai Phong Seaprodex	Hai Phong City	(potential — Proconco)
Hai Phong canning	Hai Phong City	
Phan Thiet landing port	Binh Thuan province	(potential — Proconco)
Hong Phu	Binh Thuan province	(potential — Proconco)
Ham Tan landing port	Binh Thuan province	(potential — Proconco)
Tan Tien	Ba Ria–Vung Tau province	80 t fish processed/day
Cat Lo landing port	Ba Ria–Vung Tau province	(potential — Proconco)
Dong Hai	Ba Ria–Vung Tau province	(potential — Proconco)
Ben Tre Fish meal	Ben Tre province	
Tran De landing port	Soc Trang province	(potential — Proconco)
Viet Tien	Bac Lieu province	
Ganh Hao	Bac Lieu province	(potential — Proconco)
Agrimexco	Ca Mau province	80 t fish meal/day
Ca Mau Fishery catching — Service	Ca Mau province	(potential — Proconco)
Kisimex	Kien Giang province	6500 t fish meal/year
Kien Giang Fishery Services	Can Gio district, Ho Chi Minh City	
Supporting Cafatex	Can Tho province	(potential — Proconco)
Can Tho agriculture products and foodstuff processing	Can Tho province	(potential — Proconco)
Fishery Trading	Ho Chi Minh City	

Fish meal plants using industrial cooking-dry technology have a cooker in series and a number of screw “coolers” or driers to adjust the dry matter content of the fish meal. Oil is not separated, which could result in high fat content in the meal if pelagic species are used. As priority is given to

maximum protein content for marketing, excess evaporation in the driers could increase the risk of “browning” the meal which lowers protein digestibility.

High quality fish meal cannot be manufactured because the major ingredient, mixed species of demersal fish, are degraded by the time they arrive at the plant because of sub-optimal storage. Vietnamese fishing boats usually lack insulated storage facilities and cannot carry enough ice to preserve all the catch properly. Further handling and grading at the port accelerates degradation.

Between 5–20% fish offal processing may be used when trash fish is in short supply. There is a possibility that the amount of fish and crustacean by-products from processing may increase significantly. More than 250 enterprises produce seafood products and offal from inland catfish and production is rising. Some by-products are used to produce low-value human food but the local market probably could not absorb a continued increase. However, offal cannot be used alone for fish meal production because the protein content is too low and the ash/calcium content too high. Although some is used, *Pangasius* processing waste is not a desirable raw material for fish meal manufacture because of a very high fat content that is not easily processed without fat separation. Shrimp peeling waste is also not a desirable raw material for fish meal manufacture due to low protein content and rapid degradation.

Estimates of local fish meal used to produce feeds for freshwater fish culture, marine culture, and for aquaculture in general is presented in Table 4.

Table 4. Estimates of local fish meal used to produce feeds for freshwater fish culture, marine culture, and for aquaculture in general in Vietnam. (Based on protein contents, with assumption that feed protein comes entirely from fish meal (max.) or 30% from fish meal (min.).)

Species	Production ¹ (t)	% using Pelleted Feed ²	FCR ³	Feeds (t)	Feed Protein ⁴ (%)	Fish meal Protein ⁵ (%)	Fish meal (t)		Local Fish meal ⁶ (t)	
							max	min	max	min
<i>Pangasius</i> sp.	180,000	20%	2	72,000	16%	60%	19,200	5,760	1,920	576
<i>Penaeus monodon</i>	160,000	62%	1.5	149,280	35%	60%	87,080	26,124	8,708	2,612
Total				221,280			106,280	31,884	10,628	3,188

1. *Pangasius* production from our survey; shrimp production from MOFI report (2001).
2. % using pelleted feed of catfish based on our survey; shrimp estimated from MOFI report (2001).
3. There are various kinds of pelleted feed, especially for shrimp, with different FCRs, different percentages. The figures are estimated averages.
4. Generally, protein content of feeds for catfishes and tiger shrimp are 16% and 35%, respectively.
5. Protein content of fish meal that is normally used to produce aquafeeds is 60%.
6. Local fish meal accounts for 10% of total fish meal based on our study.

As the demand for fish meal is rising rapidly, there are plans for building new plants, either as additional capacity or for the replacement of older technology. However, there is doubt in many quarters concerning their profitability. Not many ports in Vietnam can support a fish meal plant as few have sufficient supplies of trash fish. A minimum of 30 t/day of dry fish meal needs to be produced for a fish meal plant to operate profitably and few ports have the capacity to process the 120 t of wet fish required. Furthermore, there is intense competition for fish for direct human consumption, fish sauce manufacture and direct feeding to fish. The current price of trash fish is rather high for fish meal production because of such competition. If the price of trash fish continues to increase then even existing fish meal plants may not be financially viable.

The price of fish meal depends on its protein content and sells for VND 150/degree of protein, that is, with 60% protein, which is desirable for an ingredient for high quality aqua feed. Fish meal sells for VND 9000/kg. However, only limited locally manufactured fish meal attains 60% protein and the price ranges from VND 5000–9000/kg.

At least 90% of fish meal is imported. The rate of use of fish meal is increasing rapidly mainly because of the development of aquaculture. At least 150,000–200,000 t of fish meal will be required over the next decade for aquaculture, two to three times the present level of use. However, the price of imported fish meal continues to rise. Kisimex exported fish meal to Japan and Taiwan up to 1994 but ceased because of high domestic demand (an exception was 500 t exported to the Philippines in 2002).

Fish oil is not produced at present in industrial fish meal production and about 2000–3000 t are imported annually from South Korea. There is small-scale production of fish oil from *Pangasius* offal but its composition is similar to lard with a DHA content of only 0.23%. The oil is sold to ethnic minorities in Vietnam and to Cambodia for human consumption and to feed mills producing livestock feed.

Future demand for fish meal is expected to increase dramatically according to the future projections for growth of aquaculture by MOFI (1999). Furthermore, there is an increasing trend to use pelleted feed because of poor water quality in culture using “home-made” or “farm-made” feeds based on raw fish and/or crustacean by-products. Almost all shrimp culture is based on pelleted feed and the proportion used by *Pangasius* catfish farmers has reached 10–20%. Attempts are also being made to feed marine finfish and lobster with pelleted feed.

According to MOFI (1999), there were 27 feed manufacturing companies in Vietnam in 1998, with a total capacity of almost 50,000 t/year. In 1998 they produced about 10,000 t, only 10–15% of the demand for aqua feed. The rest of the demand was met from imported feed or farm-made feed (usually based on trash fish). MOFI (1999) estimated a need for 1.3–1.5 million t of industrial aqua feeds. As prospects for increased production of quality fish meal (and fish oil) do not look promising, the future development of intensive Vietnamese aquaculture is more likely to be influenced by the availability and price of fish meal and fish oil on the international market.

High market value species such as grouper, lobster and shrimp may be able to compete for fish meal on the international market. The same is unlikely to be the case for *Pangasius* and for tilapia in the future. These will need to be fed increasing amounts of plant-based proteins, including from rice bran. At least one researcher is recommending a moist formula for *Pangasius* with 5–10% fish meal, 60% rice bran and 30% soybean meal supplemented with lysine, methionine and phosphorus (Le Thanh Hung, pers. comm.).

3. Introduction

There is concern that the rapid expansion of aquaculture may be constrained in the future by dependence on low-value marine fish (“trash fish”) and fish meal which are used as aquaculture feed ingredients (Tidwell and Allan 2001; New and Wijkström 2002). Vietnam has rich living aquatic resources along its more than 3200 km coastline with about 2000 fish species described (Dang 1995). It has been recognised for some time that mariculture should be pursued as a strategy since the marine fisheries catch has reached a “critical boundary” (Dang 1995). However, much of Vietnamese coastal aquaculture (crustaceans and finfish) as well as inland aquaculture (especially *Pangasius* catfish) are dependent, either directly or indirectly on trash fish.

The Vietnamese National Program for Aquaculture Development outlined a Master Plan for the period 1999–2010 (MOFI 1999). It is predicted that “aquaculture development will help change the economic structure in rural areas, create employment, increase people’s income, improve the lives of farmers and fishers, contribute to the society order establishment and to rural security in coastal border and remote areas”. Aquaculture is also expected to meet the increasing demand for fish for domestic consumption as well as export. Planned figures for aquaculture production are a doubling and tripling of the 1999 production of 0.65 million t to 1.15 and 2.00 million t, respectively.

Thus it was timely to describe the production, uses and trends of trash fish, fish meal and fish oil in Vietnam to assess if the availability of trash fish will restrict future expansion of aquaculture in the country. The detailed terms of reference are presented in Appendix 1.

4. Methodology

A desktop survey, interviews and field visits were used to address the terms of reference. The itinerary and persons interviewed are detailed in Appendix 2. Interviews were conducted using open ended questions with key informants from R&D institutes, leading farmers and farmer organisations, fishers, fish processors and feed manufacturers, and traders. A particularly useful line of interviewing was an attempt to establish timelines by asking how the situation today compared with that of 10 years ago and opinions were canvassed on what it is likely to look like 10 years from now.

An overview of the study in relation to the terms of reference is presented in Main Findings. The following sections were derived mainly from the field survey. Notes made from a Danida funded study on fish meal and fish oil production in Vietnam (NIRAS 2001) are detailed in Appendix 3.

5. Fisheries catch and trends

The total marine fish catch in Vietnam is debatable. According to the Ministry of Fisheries (MOFI), the total catch for 2002 was estimated to be 1.4 million t compared with 0.8 million t 10 years ago. It is predicted by MOFI to reach 1.7 million t 10 years from now. Past estimates are based on provincial fisheries department reports of total catches (not broken down by species) to MOFI and several respondents questioned their reliability. Official reports have indicated catches have increased each year by about 100,000 t, but this is unrealistic as there are annual fluctuations in fish production. According to RIME, the total fishery production was 2.6 million t in 2001 (Table 1).

The Danida funded Assessment of Living Marine Resources in Vietnam (ALMRV) project has estimated marine capture fisheries production of about 2.5 million t. It is also generally agreed by FAO and ICLARM that the current Vietnamese production is between 2–3 million t based on consideration of similar fisheries in neighbouring countries.

MOFI has used the concept of maximum sustainable yield (MSY) for management of marine fisheries for the last 40 years. However, this approach has difficulties as it is impossible to estimate biomass limits from MSY. The MSY concept has been abandoned in most fisheries research and management. It is also expensive as it depends on repeated surveys. Alternative approaches use easy-to-measure indicators such as catch rates, catch composition, fish sizes and value of the catch to determine relative changes through a time series, that is, to measure trends rather than absolute numbers.

The inshore fishery is heavily over-fished and there is a need to decrease the fishing pressure. The Vietnam Government is providing soft loans with low interest rates for the purchase of boats to increase offshore fishing with the idea of reducing the pressure on inshore fisheries. However, there is no link between the two in terms of reducing the level of inshore fishing. When offshore vessels cannot catch sufficient fish offshore, they may move inshore and thus exacerbate inshore over-fishing. The Danida project (Appendix 3) did not find any significant offshore fish stocks which in general are low in tropical waters. Vietnam may have some small pelagic resources but none have yet been identified. The Vietnam Government wants to start acoustic surveys to locate potential offshore fish stocks but these are not easy to carry out as the data are difficult to interpret.

The coast of Vietnam is divided into four main zones for fishing:

- ▶ Gulf of Tonkin in north Vietnam
- ▶ Central Vietnam
- ▶ Eastern south Vietnam
- ▶ Gulf of Thailand

The estimated percentages of the total catch from major types of fishing gears are:

- ▶ Trawling 30%
- ▶ Purse seine 26%
- ▶ Gill net 18%
- ▶ Lift net 5%
- ▶ Long line 6%
- ▶ Others, for example, fixed net, push net 15%

6. Fishing

A wide range of fishing techniques are employed that catch trash fish *sensu lato*, ranging from small inshore craft that catch anchovies by light and encircling net (pha xuc) to paired trawlers that go out for up to one month with a capacity of 300 t of fish (SEAFDEC/RIMF 2002).

Catches are first sorted on board ship, placed in plastic bags and stored on ice in the hold. The most valuable species are kept separately and are unloaded first on arrival at the landing port for further sorting and sale to fish traders. Small mixed species are sorted again on the floor of the landing port, mainly by women, with separation of more trash fish.

Interviews with fishers and fish traders are outlined below.

Cat Ba Island, Hai Phong

There was no activity at Cat Ba fish landing port during the late morning visit as boats unload early in the day. However, small-scale traders were selling trash fish on Cat Ba market for pig feed at VND 2000/kg. The annual variation in the retail price of trash fish was reported to be VND 1500–3500/kg. A trader was scaling and chopping tail fins off small fish with the by-product used to feed her pigs at home.

Although large numbers of fishing boats were anchored in Cat Ba harbour, several boats were anchored by cages at aquaculture sites. A fisher's son interviewed at a cage site explained that the fishing boats unloaded their catch at Cat Ba fish landing port but that some trash fish were retained to feed fish in their cages. Fishing boats (light and encircling net, pha xuc) went out fishing for up to four days but returned early if they were lucky enough to fill the boat within the first two days. Of the 2–3 t catch, about 200–300 kg were large fish such as mackerel, dao and cuttlefish. About 70–90% comprised small fish, mainly three species that were used to feed livestock and fish, and to make fish sauce. Ten years ago it took only 1–2 days to fill the boat although the boats were smaller then. However, the fisher's son thought that the resource had declined.

Do Son, Hai Phong

A beach landing of fish was observed early in the morning. Fishing boats were anchored 50–100 m offshore and fish were being transported ashore by small boats in 10–12 kg lots, mainly high value species for human consumption.

At Do Son fish landing port, six small-scale fishers' wives, who were sorting a small pile of fish, were interviewed. They were sorting out small crabs, shrimp, squid and fish for human food, from three species of trash fish (bem bep, ot and kim bong). The trash fish were to be sold for VND 3000/kg to feed pigs, crabs, fish and shrimp. Only a few fish were caught in the cold and wet seasons compared with May and June when due to an abundance of trash fish the price falls to VND 1000/kg.

Discussions about the relative size of the catch today and 10 years ago were initially confused by the increased size of the boats. Ten years ago the maximum amount of fish caught was 100–200 kg with a minimum of 50 kg. Today, with a larger boat, the maximum was 200–300 kg in the warm season but the minimum was only 10 kg. The composition of the catch, 30% high value species and 70% trash fish, had not changed over the last 10 years.

Cu Lao fish landing port, Nha Trang

Only higher value mixed species were landed at this port in the north of the city. A woman was observed deheading small fish for human consumption with the waste used to feed pigs.

Vinh Truong fish landing port, Nha Trang

Trash fish in Nha Trang were reported to be unloaded at this port in the south of the city as it is closer to the site for cage aquaculture.

During the early morning visit, however, only high value mixed fish and grade 1 anchovy and pony fish for human food were observed in bulk. A small amount of grade 2 trash fish was observed also, destined for the manufacture of fish sauce.

According to a fisher, larger boats that fish for only one night targeted high value fish and did not use ice for anchovy. Anchovy caught at the beginning of the night were thus not fresh when unloaded and were classified as grade 2 trash fish for fish sauce manufacture. Small boats, however, used ice for all the catch. Anchovy were reported to be abundant.

Ninh Hoa district, Khanh Hoa province

Small-scale fishers were interviewed in Tan Thanh village in Nha Phu bay which had about 200 households. A wide variety of fishing gear was used which changed according to season and target species. Inshore trawling had been forbidden since 1972 and patrol boats enforced the ban. However, “butterfly” trawling was allowed to catch small fish from the surface water layer.

The fishers caught 15–20 kg each night, including 7–20 kg shrimp, the target species. Three main species of small fish were caught (bong, suot and anchovy) which could not be eaten as they had too many bones. The main season for shrimp was December to February. Shrimp was sold for VND 10,000–20,000/kg and fish for VND 500–2000/kg. Small fish, collected by middlemen on motor bikes, were used mainly to feed pigs and lobsters.

A lady fisher, who had been fishing since 1975, reported that she used to catch 20–30 kg/night, primarily the target species, shrimp. In 1975 there were only 10 fishers in the village compared with 50 today. She had no ideas concerning the likely state of the fishery over the next 10 years but reported that the supply of small fish was now stable. However, she reported that not many fishers were interested in catching small fish as the price was low. Small fish are caught on order from lobster farmers. The main business of fishers at the time of the interview was lobster seed collection for which they received VND 80,000–130,000/individual piece.

Cam Ranh

A fish farmer reported that small-scale fishers using gill nets caught 40–50 kg trash fish/day, as well as swimming crabs. Their wives sold the trash fish in the local market at VND 3000–4000/kg for feeding pigs and grouper. However, the fish farmer preferred to buy trash fish from the local fish landing port as it was cheaper, even though it was not as fresh.

Rach Gia

A fishing boat owner at the main fish landing port in Rach Gia, the provincial capital of Kien Giang, who had been in the business for 30 years reported that trawlers caught 30 t of high value fish and about 15–20 t of trash fish, all of which was sorted at sea and stored in plastic bags on ice. About 40 species were caught.

30 years ago the trawlers were only of 5 t capacity and fished inshore. There were fewer large fish but most of the catch was for human consumption.

The interviewee expected the amount of fish to decline over the next 10 years as there were 7000 fishing boats in the province and the number was increasing, with the fishing grounds expanding to Vung Tau. However, she also believed that fish would be caught further offshore with larger boats in 10 years' time.

A fish trader with 15 years' experience reported that he had not seen any changes in fish catches. Larger fish had already been sorted out on board the boat and smaller fish were being sorted on the quayside. The average price of small fish for human consumption was VND 7000/kg compared with VND 2000–3000/kg for trash fish. Several species of trash fish were photographed. Only 1% of the catch unloaded here was trash fish, sorted from the other small fish on the quayside, as most of the trash fish remained on the boat in plastic bags for transport to fish sauce and fish meal factories because there was no cage culture in the area (only at Ha Tien on the Cambodia border). The trader predicted that over the next 10 years the resource will decline, its composition will change with perhaps an increase in the percentage of trash fish, and the price will rise. Since the liberalisation of the market (doi moi) in 1984, the number of fishing boats has increased.

Cao Van Thong, the provincial aquaculture extensionist, reported that the amount of trash fish depended on the fishing technique, with 80% of the catch of trawlers comprising trash fish according to provincial records. Anchovy was fished by a specialised method. Trawlers went out for 15–20 days and all fish caught were put in plastic bags on ice and brought back, including trash fish. In the past they used larger sized mesh and caught mainly large fish and any small fish caught were thrown away.

Vung Tau fish landing port

A fisher with 18 years' experience was interviewed. He reported that boats varied in size and were single and paired trawlers, catching up to 100–120 t of mixed fish species. The “trash fish” leather jacket was the main species, comprising up to 60–90% of the total catch. There was more mixed fish in the past, according to the fisher. Boats were smaller and as fish were abundant the fishers were selective about what fish were brought back to port (landed). Previously leather jacket was thrown back into the sea but now everything is landed.

Discussion about interpreting changes in the fishery over time were complicated by changes in the number and size of boats. Eighteen years ago one trip in a small boat lasted 9–15 days and there was little trash fish. Today trips in larger boats lasted 23–40 days and more Grade 3 fish are caught. The fisher thought that the total production had declined but that there had been a tremendous increase in fishing effort. Compared with 18 years ago the number of boats had increased by a factor of eight and their horsepower had doubled from <100 to >200. Shipyards were making even larger boats. Phan Van Manh, the local shrimp hatchery owner who accompanied us, agreed that the total catch of fish must have gone up with such a large increase in the number and size of boats, but added that fishers need to fish for longer and further away. Fishing grounds used to be only 40 miles away but now extend more than 300 miles, even to Indonesia. The fisher expected the resource to decline further over the next 10 years. This would mean having to spend longer at sea, which would also lead to a decline in the quality of fish. Fuel prices continued to rise but fish prices were stable, causing concern for the future.

A fish trader reported lots of mixed fish in the past compared with today, with only 10% mixed fresh fish for the local market, 80% of fish for drying and 10% “pig” or trash fish. Grade 1 small fish was for direct human food as fresh fish, Grade 2 fish was dried with by-products or waste going for fish meal production, and Grade 3 was for feeding pigs and fish. Prior to drying, fish flesh was separated from head, bones and offal.

7. Trash fish

There is no special fishery for trash fish in Vietnam, that is, it is only a by-catch. However, it is the most important fish product in terms of both weight and value. Trash fish is caught mainly from trawling. With selected gear such as long line or large 10 cm gill nets, only large fish are caught with trash fish comprising about 1% of the total catch. Trash fish may comprise up to 60% of the total catch in inshore waters but less offshore where migratory pelagic species like tuna and tuna-like species are targeted.

There are many trash fish species (Table 2), the composition of which depends on the fishing area and the type of gear. There are three terms for trash fish in Vietnamese: trash fish, trawler fish and pig fish, the latter being the lowest quality only and therefore having a more restricted meaning than the other two terms.

The identification of trash fish is not always clear. Previously it was fish of low to no economic value but some such fish are now being converted into value added products. Leatherjacket is a very bony fish which was rarely eaten before the development of processing technology. It was either only salted and converted into fish sauce, or even used as a fertiliser in south Vietnam. It was often thrown away. Three to four years ago a process was introduced involving drying it for export and now it has economic value and is thus now not a trash fish. Pony fish also used to have low value but now it is used to feed grouper, cobia and other species.

The catch composition is changing, with an increase in trash fish, especially from trawling. When fish resources were abundant, the percentage of trash fish was low, only 30–40%, but now it may be as high as 50–60%, especially from inshore areas, depending on fishing zone. There is less trash fish in the north than the south. Because of intense fishing pressure the largest percentage of trash fish in the catch is in the Gulf of Thailand; the second largest percentage is east of south Vietnam, and the third largest percentage is the Gulf of Tonkin and fourth largest is central Vietnam, where mainly selective gears are used in deep water.

MOFI estimated production of 200,000 t of trash fish from a total catch of 1.4 million t in 2002 or 14% of the total. This represents “real” trash fish, not including another 200,000 t of more valuable small species such as leatherjacket and pony fish, formerly considered as trash fish. Another 20% of the catch would be small individuals of fish such as grouper which would be a valuable species if large, leading to a sum of about 50% for trash fish *sensu lato* in the total catch. RIMF estimated the trash fish production was 0.93 million t from a total fish catch of 2.6 million t in 2001 (Table 1).

Although there are no official data on the use of trash fish for aquaculture in Vietnam, an estimate can be made based on the production of key species that are fed trash fish. The proportion fed trash, their food conversion ratio and an estimate of the amount of trash fish in their rations is presented in Table 5.

Even though fishing technology has improved with better targeting of high value species, the biomass of trash fish continues to rise. Over-fishing has reduced the grazing pressure on small fish by larger predatory fish, for example pony fish has increased in abundance. Questions of how much trash fish is increasing, for what reasons and likely future trends are of importance for both capture fisheries and other industries depending on by-products such as aquaculture. Essentially, the main question is: what are the relationships between increasing degradation of inshore fisheries and increasing supplies of trash fish?

Table 5. Estimate of trash fish used to produce freshwater and marine species in Vietnam.

Species	Production (mt)	% using trash fish	FCR	Moist/wet feed (t)	Trashfish (t)	
					Min	Max
Pangasius catfish	180,000	80%	2.5	360,000	64,800	180,000
Shrimp (<i>Penaeus monodon</i>)	160,000	38%	4.75	287,280	71,820	143,640
Marine fishes (grouper)	2,000	100%	5.9	11,800	11,800	11,800
Lobster (<i>P. ornatus</i>)	1,000	100%	28	28,000	28,000	28,000
Total				687,080	176,420	363,440

Trash fish used for inland, coastal and overall aquaculture in Vietnam were estimated to be between 64,800 t and 180,000 t; between 72,000 t and 144,000 t; and between 177,000 t and 364,000 t, respectively.

According to MOFI, the percentage use of the marine finfish catch is as follows:

- ▶ export — 20%
- ▶ fresh human consumption in Vietnam — 20%
- ▶ feeding to animals (livestock, aquaculture) and fish meal — 25%
- ▶ fish sauce — 25%.

The quality of trash fish is a major concern. Even though it has a high protein content and quality when caught, the quality declines rapidly as only ice or chilled water is used to preserve it on board ship. Storage of trash fish is a problem, especially in offshore fisheries, as boats may be at sea from 1–4 weeks. According to an article in the Vietnamese newspaper Tuoi Tre (24 February 2003), 20–30% and even 50–60% of high value fish on some offshore trawlers becomes waste because of poor storage.

About 8000 t of trash fish are exported to China's international border from Cat Ba Island in Hai Phong, north Vietnam. Leather jacket and anchovy are also exported to China after processing, mainly from Binh Thuan province in south Vietnam. Trash fish are not imported into Vietnam, only high value fish such as salmon.

There are several different uses for trash fish:

- ▶ fish sauce
- ▶ direct human food
- ▶ livestock feed
- ▶ aquaculture feed.

The use of trash fish depends on location. For example, it is mainly used for fish sauce on Phu Quoc island in Kien Giang province. Phan Thiet in Binh Thuan province is a large port where most of the trash fish is used for fish sauce. Some trash fish landed at Phan Thiet is dried as human food and is marketed in mountainous inland areas. Processing trash fish for surimi is a recently developed process, but aquaculturists can pay more for trash fish (up to VND 5000/kg for grouper culture) than processors of surimi. Pigs in coastal areas are traditionally fed trash fish with rice bran, water spinach and banana stems. Pigs were raised in Tan Thanh fishing village in the Ninh Hoa district of Khanh Hoa province by people who were unable to go fishing. The most recent use of trash fish is for coastal aquaculture, the development of which depends on trash fish. As one respondent put it, without trash fish 'it is not possible to do aquaculture'. The demand for trash fish for cage culture is a contributory factor to the recent doubling in the price of trash fish.

The Danida funded ALMRV project with RIMF has characterised fisheries resources, including trash fish (Appendix 3). The first phase, which has been completed, covered 11 coastal provinces and the second, ongoing phase is covering all 28 coastal provinces. In Phase 1, data were collected on species composition of the catch by species and weight — both so-called mixed or commercial species of value, and trash fish. In Phase 2, biological characteristics of species are not being collected, only the commercial aspects. Each province has different commercial groups depending to some extent on what the fishers target. For example, in Hai Phong fishers mainly target shrimp as well as mixed fish species.

There is an enumerator network in all 28 coastal provinces recording the total catch and its composition daily at each port. Several databases contain the following information:

- ▶ survey data from research vessels
- ▶ commercial fisheries at fish landing places
- ▶ data from RIMF staff sent on commercial boats
- ▶ log books of fishers.

Species are identified in haul data, but it is very difficult to identify all species from trawls as there are more than 100 species. Another species category is used for trash fish that cannot be identified to species level. However, trash fish are identified at least to genus. Some samples have “other biomass” recorded to cover invertebrates also. Since 1996 fishers have been interviewed at landing places as they sort out the catch, with samples taken from each group and identified to species.

RIMF has several small projects on commercial fisheries but not one on by-catch as MOFI apparently does not appreciate its importance. Another source of funding is being sought to analyse existing data sets to determine the future balance between mixed species and trash fish. There is a need to examine the amount and species composition of trash fish to try to establish the reasons for changes.

RIMF has a MOFI funded project on small pelagics, which comprise >40% of the inshore catch, to study their balance with demersal fish. There is also a SEAFDEC funded project on small pelagics. Another project is the EU/Danida funded project “Know fish” involving RIMF, University of Can Tho and MOFI’s Planning and Investment Department as well as the University of Wageningen and the Danish Institute of Fishery Research. The objective is to identify and use local knowledge for fisheries management. Fishers are being interviewed to find out what they consider to be the major characteristics and issues relating to fisheries. These will be summarised and presented to a workshop of fishers so that indicators can be identified that both fishers and scientists can agree upon.

8. Fish sauce

Small-scale manufacture of fish sauce at the household level is a traditional practice throughout coastal Vietnam. The best quality, for which only anchovy (*Stolephorus* sp.) is used, comes from Phu Quoc island in Kien Giang province. Discussions were held with fish sauce manufacturers in Binh Tan commune in Nha Trang and on the mainland of Kien Giang province.

There were several households manufacturing fish sauce in Binh Tan commune. The best quality was made with anchovy, followed by scad and cardinal fish. There were three grades of anchovy: Grade 1 costing VND 7000–10,000/kg was steam dried and used in rice soup as well as for export; Grade 2 costing VND 4000–5000/kg was used for grouper culture; and Grade 3 costing VND 1000–4000/kg was used for fish sauce (Grade 2 was sometimes used as well). The price of high quality fish sauce rose over the past 10 years from VND 7000 to VND 20,000/L because of increasing demand and higher production cost.

A visit was made to the Van Loi fish sauce factory, a small-scale operation in Binh Tan commune in Nha Trang which had been making fish sauce for 50 years. Fifteen families made fish sauce but only three were large scale, making at least 5 million L/year. Van Loi made 500,000 L/year and, in common with the whole commune, had increased production by a factor of 15 over the last 10 years. The factory sold wholesale at VND 10,000/L, mainly to Hanoi for export to eastern Europe. The price remained stable over the last 10 years. A 50% increase in production was expected over the next 10 years as the Nha Trang brand became as famous as those from Phu Quoc and Phan Thiet. According to the factory owner, the price of raw material was stable at VND 1000–3500/kg for Grades 2 and 3 anchovy, which were not so fresh. The supply of anchovy was expected to be sufficient over the next 10 years. Furthermore, there was no competition for anchovy for feeding grouper as the latter required better quality fish.

The Nam Phuong Fish Sauce Company in Kien Giang province has produced fish sauce for more than 100 years, mainly for the domestic market. The factory produced 2 million L/year compared with only 0.8 million L/year 10 years ago, almost a three fold increase. In the past, anchovy, clupeids, scad and mixed trash fish were used to make fish sauce, but since 2002 anchovy was mainly used because the price of mixed trash fish had increased as it was now being used for aquaculture. They used anchovy salted on the fishing boat at VND 3000–3500/kg. The price of fresh mixed trash fish was still cheaper at VND 2000–3000/kg but the quality of the fish sauce would also be lower. Fish sauce made from anchovy had a higher protein content and was not smelly. Furthermore, the manufacturing process was simpler and less harmful to the workers. Anchovy fish sauce came in 10 grades ranging in price from VND 1000–15,000/L compared to three grades made from trash fish at VND 800–2000/L. It was more profitable to produce anchovy fish sauce as it sold for a higher price. In contrast, fish sauce made from trash fish was mainly for the poor. Although the demand for higher value fish sauce was increasing, the needs of poor people would be catered for by other factories as there was a total of 300 fish sauce factories in the province with a total production of 24 million L.

The number of fish sauce factories in Kien Giang province increased by 30% but the capacity doubled. In ten years' time the production of fish sauce is expected to double as each person is likely to require 2 L/year of fish sauce and the population is rising. The national production of fish sauce is forecast to rise to 160 million L/year in 10 years, double today's production of 80 million L/year. The biggest problem is likely to be an inadequate supply of raw material. The fishery resource has declined from over-fishing. Ten years ago the composition of the catch was at least 50% large fish,

but now it has fallen to 20%, that is, 80% trash fish. However, there is increasing competition from other fish sauce factories as well as from aquaculture. Two years ago the price of mixed trash fish was VND 800/kg all year round but now it had increased to VND 2000–3000/kg. The price of anchovy had similarly risen from VND 1700–2200/kg to VND 3000–3500/kg. Anchovy was rarely used in cage culture because it is difficult to store on ice as the flesh is very soft and breaks down readily. Thus there was limited competition between fish sauce manufacture and cage culture in the Mekong delta. Competition was within the fish sauce industry and with drying for human food for export (only a little dried fish was consumed locally).

9. Fish and crustacean processing waste

An insight into processing wastes was gained from visits to small-scale fish processing factories in Kien Giang and Ba Ria-Vung Tau provinces.

In Rach Gia city there are about 100 processing factories. There were reported to be eight large processing factories in Rach Gia city belonging to Kisimex Company. The Company is also involved in fish sauce and fish meal manufacture. An average small-scale fish processing factory was visited that processes 10–20 t of six species per month from which 4–5 t of heads and “guts” are produced as by-products. “Guts” were sold for VND 1000–1500/kg.

Fish were transported to Ben Da from Cat Lo Port in Vung Tau (about 15 km) because there are a number of small-scale fish processing facilities located near Ben Da, in Sao Mai. According to a fish dealer at Ben Da, the landings of fish increased markedly three years ago when off-shore fishing commenced. The catches unloaded comprised about 20% large mixed species of fish, 40% of fish for surimi production and 40% of fish for drying, with more or less no trash fish. Trash fish was not caught presumably because of off-shore fishing. Surimi is minced fish flesh, steamed and made into cakes. White fish flesh is used, mainly from lizardfish but also from bigeye. It is mainly produced in Vung Tau for export to Korea.

About 40% of the fish used for surimi production is “waste” while about 20% of the fish used for drying is “waste”. Waste or by-products are used for fish meal production. There were about 15 sites for traditional fish processing in Vung Tau, including one very large site. In addition there were seven modern fish processing factories for squid.

Traditional small-scale fish processing was observed at Sao Mai in Vung Tau where ray and pomfret were being sun-dried, and flesh was being removed from lizard fish and bigeye for surimi. Some fish by-products were being fed to pigs locally but most was destined for fish meal factories. The cottage level traditional processing employed mainly women and children.

According to Williams (2000), the Nha Trang Seafoods Factory F18 processed 70–80% of all processed fish in Khanh Hoa province, producing 1500 t of by-products. Of this, 50% was sun-dried and used to make fish meal, 30% was used to make fish sauce and 20% was for direct human food. Intensive shrimp production of 2000 t produced 1000 t of wet waste that led to 300 t of dried shrimp head meal, which was used by feed mills.

Large amounts of processing wastes were currently being generated but as the technology to process fish for human food improves there will be less by-product for feed and other uses.

10. Fish meal

There are two main ways of producing fish meal:

- ▶ The traditional, artisanal way of direct drying which produces “fish powder”, used mainly to feed pigs and poultry.
- ▶ An industrial process in which the raw materials are cooked before being dried.

Many fish meal factories use the traditional method in which trash fish is sun-dried before grinding. However, one respondent was of the opinion that it should be banned because of bacterial contamination of the final product.

A list of fish meal plants in Vietnam is presented in Table 3. Most are in the south where there is the greatest supply of trash fish.

The quality of Vietnamese fish meal is regarded as being of low quality with low protein content (a maximum of 60% for a limited amount of the product) and high histamine and cadaverine concentrations. Fish meal is produced from trash fish, low value fish (sharks), spoiled fish and processing wastes. Over 500,000 t of fish are processed producing 300,000 t of processing by-products. Trash fish varies in quality seasonally and is of poor quality as it is often left for over one week on board with limited or no preservation.

Vietnam used at least 60,000 t of fish meal last year, at least 90% of which was imported. The rate of use of fish meal is increasing rapidly because of the development of aquaculture. To support future predicted growth of aquaculture, at least 150,000–200,000 t of fish meal will be required. One feed mill, Proconco, imports about 10,000 t fish meal annually. However, the price of imported fish meal continues to rise. The most reliable way to estimate the use of fish meal is to back calculate from aquaculture production statistics.

As the demand for fish meal is rising rapidly, investment has been made in at least 10 new fish meal plants, although there is doubt in many quarters concerning their likely profitability. If each new plant produces at a nominal capacity of 30,000 t/year, this would provide for another 300,000 t of fish meal. Ideally 50–100 t per day of fish need to be processed (giving a minimum of 30 t/per day of fish meal) for a fish meal plant to operate profitably. Few companies can achieve this because most ports in Vietnam are too small.

One respondent was of the opinion that it would be impossible to set up a modern fish meal factory in north Vietnam. The two existing plants in Hai Phong probably use mainly fish processing by-products from the traditional artisanal process to produce fish powder. A request to visit Hai Phong Canning Company through RIMF was not successful. One of the most suitable places to establish fish meal production is Vung Tau where SEAPRODEX has built a new plant. Vung Tau is the largest port, with fishing boats landing from other provinces because they can get higher prices for fish as Vung Tau is near the centre of fish consumption. Ice and fuel can also be purchased at lower prices than at other ports.

In response to the problem of relatively small amounts of raw material available at fishing ports, A & S Thai Works Co. Ltd. (Agent and Licensee for Atlas-Stord, Norway) has developed containerised fish meal plants, complete with steam boilers, that can be installed on a barge moored at port. A 40 t/day plant costs US\$450,000. Additional advantages are that there is no smell from fish meal manufacture as the plant is not on land, fresher fish are used for processing, there are lower handling and transportation costs, and the plant can be moved if raw material supply declines. The company had sold five plants in Vietnam, three of which were purchased by Proconco.

The price of trash fish for fish meal production is rather high because of competition for it for fish sauce manufacture and more recently from direct use in fish culture. Previously trash fish was also used as a crop fertiliser.

The price of fish meal depends on its protein content. It sells for VND 150/degree of protein; that is, if fish meal has 60% protein it costs 150×60 or VND 9000/kg. Vietnamese fish meal ranges in price from VND 5000–9000/kg. However, the price also depends on factory and season. If low cost trash fish can be purchased at VND 1200/kg then the price of fish meal would be low. However, if the fish is leather jacket at VND 1800/kg then the fish meal would have a higher price. If traders can sell leather jacket for filleting at VND 2000/kg, then it is a problem for fish meal factories. Fish sauce factories can also afford to buy trash fish at VND 100–200/kg, a higher price than fish meal factories can usually afford.

One reason for insufficient supply of trash fish for fish meal manufacture is because about one third of the fishery catch is thrown overboard. Fishers need improved technology so a higher percentage of the catch can be landed.

The rapidly expanding culture of *Pangasius* catfish can provide plenty of raw material for fish meal production in the future, according to one respondent. Processing catfish produces 70% offal which is processed in traditional, artisanal ways at present. The Government forecasts that today's catfish production of 150,000 t will increase to 450,000 t, which will produce 300,000 t of offal. Fish meal production could play an increasing role in the profitable handling of catfish processing by-products.

Although entry to the factory and farm were denied, insight into the local fish meal market was provided by a visit to the Asian Hawaii Venture in Phu Yen province. The company is a combined feed mill and shrimp farm, mainly for white leg shrimp (*Litopenaeus vannamei*) using imported broodstock. They have a shrimp hatchery and a 50 ha demonstration farm. Their aim is to provide local farmers with seed, feed and technology and to buy farmers' produce for processing and export to the USA. They also have demonstration farms in Hue, Binh Dinh and Ben Tre and were looking to set up farms in Khanh Hoa, Ninh Thuan and Binh Thuan. They were also considering farming red tilapia. The Company imported fish meal from Malaysia via a local distributor in Vung Tau. Hai Phong Canning Company fish meal did not meet their protein requirement of 60% but they indicated that, to lower their costs, they would use local fish meal if the quality improved in the future.

Kisimex Fish Meal Factory was visited but only Le Anh Tuan was allowed to enter. Last year 6300 t of fish meal were produced, Grades 1 and 2 with protein contents and prices of 60% and 55% and VND 7000–8500 and VND 6000–7500/kg, respectively. Fish oil was not made. Trash fish was observed being delivered by boat in plastic bags, without ice, and the fish were already decaying as indicated by the bad smell. Before 2001, the fish meal was mainly used to feed livestock, but for the last two years it was also used for aquaculture. Last year 500 t of fish meal were exported to the Philippines. The Company feared that there would not be enough trash fish to meet demand if the Government introduced a ban on inshore fishing.

RIA No. 2 has developed a small-scale fish meal plant at laboratory scale to produce fish meal with a protein content >60% and with a low ash content. Large-scale production of fish meal in Vietnam was reported to produce a product with high ash content as the raw material includes the head and bones. These are separated from fish flesh in the new technology used by RIA No. 2.

Local fish meal used to produce feeds for aquaculture in general are estimated (in two ways) to be between 3188 t and 10,628 t (see Table 4 for details of calculations).

This estimate meets with difficulties for the following reasons:

- ▶ There are three (even four) types of shrimp culture including (improved) extensive, semi-intensive and intensive, but there are no data related to the proportion of each type.
- ▶ There are various kinds of pelleted feed; for example, more than 42 feed types for one stage with different FCRs.
- ▶ Fish meal came from various sources (local, imported) and its protein content varied.

11. Fish oil

At the present time Vietnam does not produce fish oil in the fish meal production process. Fish oil is imported from South Korea. About 2000–3000 t of fish oil are currently used in the feed industry. A factory in Hai Phong makes fish oil from fish livers and there is local production of squid oil in Nha Trang.

However, there is small-scale production of fish oil from *Pangasius* catfish in the Mekong delta. Agifish Company also has a plant. Offal is purchased from filleting factories and is cooked at 70°C. The oil, which floats to the surface, is collected and filtered. It costs VND 3000/L. It is mainly used in livestock feed and as an edible oil for humans. The composition of basa oil is similar to that of lard although it has a very low DHA content of 0.23%

The oil content of tropical fish is low, with the exception of *Pangasius* catfish, and this constrains local production of fish oil with high contents of long chain unsaturated fatty acids such as DHA.

12. Formulated aqua feed

Locally produced fish meal is mainly used as an ingredient in livestock feed although some feedmills, including Proconco, use it in grow-out feed for fish. However, high quality fish meal, imported mainly from Peru, is used to formulate feed for fish fry and for shrimp. All fish pellets are floating with a protein content ranging from 30–32% for fingerlings and 18–20% for large fish. Fish meal inclusion rates range from 5–30% for fish diets and 20–50% for shrimp feed.

RIA No. 2 is conducting research on alternative protein sources, soybean meal and fish hydrolysate, for *Pangasius* and *Oreochromis*. It has been possible to replace 80% of fish meal with soybean. The production of fish hydrolysate using protease enzymes on low grade fish and trash fish is being investigated on a laboratory scale.

University of Agriculture and Forestry, Ho Chi Minh City is also carrying out research on alternative protein sources, soybean, groundnut meal and rubber oil cake, for *P. bocourti* and *P. hypophthalmus*. It has been shown that certain plant meals can almost totally replace fish meal in the diet.

At University of Fisheries, Nha Trang, as part of his PhD research, Le Anh Tuan is conducting a study on the development of compounded pellet diets for grouper (*Epinephelus malabaricus*). Research objectives are to determine optimum dietary protein and lipid (energy) requirements; determine apparent digestibility of main feed ingredients; and examine if terrestrial protein meals (soybean, meat meal, etc) can substitute for fish meal. Some preliminary findings show that the growth rate and FCR improved linearly with increasing dietary crude protein up to max of 50% DM; no effect of increased dietary lipid from 17% to 37% DM; fish fed high lipid diets were fatter; and isonitrogenous replacement of fish meal with meat meal or soybean meal resulted in poorer growth and FCR.

Clearly it will be impossible to meet Vietnam's target for future aquaculture production without a considerable increase in the use of industrial feed. Feed mills are responding to this reality. Proconco produced 500 t of *Pangasius* pellets two years ago but 4000 t this year, that is a fourfold increase. With the Government target of 200,000 t of catfish, there will need to be further marked increases in formulated aqua feed production.

13. Aquaculture

Aquaculture species in Vietnam by group and major species with current and future estimated production are presented in Tables 6 and 7.

Cat Ba Island, Hai Phong

Cages were visited belonging to RIA No. 1 and a private farmer. According to the RIA No. 1 cage site manager, cage culture started in 1990, but there are now almost 4000 cages at three sites in Cat Ba. Farmers were farming two species of grouper (*E. coioides* and *E. malabaricus*) and cobia.

As local farmers used only trash fish as feed, a project through MOFI focussed on reducing pollution from cage culture. Fish were fed once a day compared with twice a day previously; and small fish of about 100 g were fed a moist minced diet of trash fish and locally produced fish meal at a 1:0.7 ratio. Larger fish were fed only trash fish. Trash fish were most abundant from January to June, with the amount declining over the year as less fish were caught in the rainy season, when it was cold. A better growth rate was obtained with a diet of only trash fish, which also was cheaper.

A private farmer reported that he preferred to farm grouper rather than cobia because grouper had a higher farm gate price as it was exported. First grade grouper, 1–1.5 kg, fetched VND 135,000/kg, 1.5–2.5 kg fetched VND 115,000 and fish >2.5 kg fetched an even lower price. Normally, grouper was sold at 0.9–1 kg and took one year to culture. Grouper fingerlings of 5–8 cm caught by hook and line cost VND 4000 each, but the mortality rate prior to stocking in cages was high with only about 33% survival. Trash fish from Cat Bai port costing from VND 2500–3500/kg (up to VND 7000/kg during the Tet holidays when few fishers worked) was delivered to the cage farm by a trader. In previous years trash fish was always abundant, but there were periodic shortages in the current year. Three years ago the trash fish price was <VND 2000/kg, but at the time it was an average of VND 3000/kg. The farmer was worried about the future supply and price of trash fish, saying that 10 fishers now provide for 20 cage farmers whereas in future they may have to provide for 100 farmers.

Five years ago the farmer cultured grouper in ponds but he sold out as he lacked investment to purchase seed and feed for his 3 ha farm. Apparently better-off farmers invest in pond culture.

The boatman, who also had a floating restaurant and cages, reported that cobia was also caught for stocking cages by hook and line, usually at 0.7–1 kg. Although the price was lower than grouper at VND 70–80,000/kg, the growth rate was much faster and stocked fish soon attained a size of 10 kg.

Do Son, Hai Phong

1100 ha of ponds were used to culture tiger shrimp from April–August, with 900 inside the dike and 200 ha outside the dike. For the remainder of the year the seaweed *Gracilaria* and mud crab are usually grown with occasional culture of tilapia or other species. Outside the dike the clam *Meretrix* was farmed, with wild seed obtained from Nam Ha. *Gracilaria* was dried and exported to China.

From 1992 an EU-funded project introduced a seaweed culture system for returned boat people, but at the present time the farmers are engaged in polyculture involving higher value shrimp and crabs. One thousand poor farming households were each allocated 1 ha of land. Originally they were poor rice farmers. To prevent the area from being inundated by the sea, the Government invested in a 16–17 km-long dike, which extended to Hai Phong city. The farmers raised shrimp mainly with minced trash fish. However, farmers were reported to be changing to pelleted feed, either

farm-made, local Vietnamese feed or imported brands from China, Korea, Taiwan or Thailand. Farm-made feeds comprised trash fish minced with fish meal from two factories in Hai Phong. The feeds were sun-dried although this process was not observed because it was out of season. Disease was reported to be a problem. Mud crab was fed chopped trash fish and chopped bivalves. A crab hatchery was under construction by a local Vietnamese company with technical assistance from RIA No. 3.

Table 6. Aquaculture species in Vietnam by group.

Scientific name	English name	Vietnamese name	Current production (2000) (t)	Future production (by 2010) (t)
<i>Oreochromis</i> spp, <i>Pangasius</i> spp, <i>Ctenopharyngodon idellus</i> , <i>Cirrhina molitorella</i> , <i>Labeo rohita</i> , <i>Oxyeleotris marmoratus</i> , <i>Osphronemus gorami</i> , <i>Barbodes gonionotus</i> , <i>Clarias</i> , <i>Channa</i> , <i>Trichogaster pectoralis</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Monopterus albus</i>	Pond Freshwater fishes hybrid carp, tilapia, pangasius catfishes, grass carp, mud carp, indian carp, goby, giant gouramy, silver barb, walking catfish, snakehead, snakeskin gouramy, silver carp, bighead carp, eel	Ca nuoc ngot nuoi ao Chep lai, ro phi, tra tram co, troi, rohu, bong tuong, tai tuong, me vinh, tre, qua/loc, sac ran, me (trang, hoa), luon	All freshwater fish production = 386,000 t	480,000
<i>Cyprinus carpio</i> , <i>Oreochromis</i> spp, <i>Macrobrachium rosenbergii</i> , <i>Trichogaster pectoralis</i> , <i>Clarias</i> spp, <i>Channa</i>	Rice field Freshwater fishes Common carp, tilapia, giant freshwater prawn, snakeskin gouramy, walking catfish, snakehead	Ca nuoc ngot nuoi ruong Chep, ro phi, tom cang xanh, sac ran, tre, loc	unknown	170,000
<i>Pangasius</i> spp, <i>Oxyeleotris marmoratus</i> , <i>Oreochromis</i> spp; <i>Cyprinus carpio</i> , <i>Cirrhina molitorella</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idellus</i> , <i>Labeo rohita</i>)	Reservoir/river Freshwater fishes Pagasius catfishes, goby, tilapia, carp, mud carp, silver carp, bighead carp, grass carp, Indian carp, mrigal	Ca nuoc ngot nuoi bo chua/song Ba sa, tra, bong tuong, ro phi, chep, troi, me tram co, rohu, mrigal	unknown	220,000
<i>Macrobrachium</i> <i>Panulirus ornatus</i> <i>Epinephelus</i> spp, <i>Lutjanus</i> spp, <i>Pacrosomus major</i> , <i>Lates calcarifer</i> , <i>Chanos chanos</i>	Giant prawn, Penaeid shrimp Rock lobster Marine fishes		4,000 150,000 1,000	60,000 360,000
<i>Meretrix</i> spp, <i>Arca granosa</i> , <i>Babylon babylonsa</i> , <i>Pinctada</i> spp, <i>Chlamys nobilis</i> , <i>Ostrea</i> spp, <i>Haliotis</i> spp	Molluscs Clam, blood ark, sweet snail, pearl oyster, scallop, oyster, abalone	Nhuven the Ngheu/ngao, so huyet, oc huong, trai ngoc, diep, bao ngu, hau	102,000	380,000
<i>Gracilaria</i> spp, <i>Kappaphycus alvarezii</i>	Seaweeds	Rong bien Rong cau, Rong sun	10,000	550,000 (Wet wt)

Table 7. Major aquaculture species in Vietnam.

Scientific Name	English name	Vietnamese name	Current production (2002) t	Future production (by 2010) t
<i>Pangasius bocourti</i>	Basa catfish	Ca Ba sa	+++	++++
<i>Pangasius hypophthalmus</i>	Tra catfish	Ca Tra	+++++	+++++
<i>Piaractus brachypomus</i>	Pirapitinga	Ca Chim trang	+	++
<i>Oreochromis</i> spp	Tilapia	Ca Ro phi	++	++++
<i>Cyprinus carpio</i>	Common carp	Ca Chep	++	++++
<i>Clarias</i> spp	Walking catfish	Ca tre	++	++++
<i>Macrobrachium rosenbergii</i>	Giant freshwater prawn	Tom cang xanh	++	++++
<i>Penaeidae</i>	Penaeid shrimp	Tom he	+++++	+++++
<i>Panulirus ornatus</i>	Spiny lobster	Tom hum	++	+++
<i>Scylla serrata</i>	Mud crab	Cua xanh	++	+++
<i>Epinephelus</i> spp	Grouper	Ca mu	++	++++
<i>Rachyentron canadum</i>	Cobia	Ca bop/gio	+	+++
<i>Lutjanus</i> spp	Snapper	Ca hong	+	+++
<i>Pacrosomus major</i>	Red sea bream	Ca trap	+	+++
<i>Lutjanus</i> spp	Asian seabass, barramundi	Ca vuoc/chem	+	+++
<i>Chanos chanos</i>	Milk fish	Ca mang bien	+	+++

+ <1000 t
 ++ 1000–10,000 t
 +++ 10000–50,000 t
 ++++ 50000–100,000 t
 +++++ >100,000 t

A shrimp and crab farmer, one of the pioneers in the area, was interviewed. Previously he was a rice farmer with 3000 m² of land with fish (grass carp, rohu and tilapia) cultured in farm irrigation ditches using nightsoil. He converted to shrimp culture seven years ago. Only farmers near Hai Phong still cultured fish using nightsoil as all farmers in the area had shifted to shrimp. Although previously he was a poor farmer, aquaculture had improved his life considerably; he had a modern style brick house, a colour TV and a motorbike. He was also a seed supplier, distributing shrimp seed from Da Nang and crab seed from Quang Binh. For the first two years after starting shrimp culture, he used an extensive system based only on natural food and tidal exchange. In the third year he started to use KP 90 pelleted feed from DaNang, supplemented with trash fish only once a week as he was afraid of poor water quality. Other farmers in the area practised similar methods. The farmer interviewed used CP or KP pelleted feed for PL₁₅ to size 2–3 cm, Ha Long Co. pellets and trash fish once a week, until one month before harvest, and for the last month he used trash fish daily as shrimp grow better. However, he was concerned about trash fish adversely affecting water quality as he had only four successful crops out of 14 due to disease. Crabs were fed small molluscs. Prices for pelleted feed were Ha Long Company VND 9000 and VND 11,000/kg depending on type, KP from Da Nang VND 19,000 and imported CP VND 30,000/kg. Seven years ago only KP 90 was available. Trash fish had increased in price from VND 500–1500/kg to VND 1000–2500 with an average of VND 1500/kg. As the farmer only needed 5 kg trash fish daily it was easy to purchase it from fishers' wives at the market, but he was concerned about the trash fish supply in the future which he expected to decline and he expected the price to increase. His biggest problems were water quality and lack of money to invest as he had failed so many times. He had never received any technical assistance and had never seen an extensionist. Feed was still available but prices continued to increase.

Dr Vu Dung informed us that RIA No. 1 had a joint venture with a local company in Quang Ninh province. The Institute gave 20,000 grouper fingerlings to stock 4 ha of ponds. Growth rate in ponds was said to be faster than in cages. Trash fish was being fed with an expected FCR of 6. Survival rate was very low because of disease, 20–30 to a maximum of 50%. However, the operation was expected to be profitable as trash fish cost only VND 2000/kg compared with grouper farm gate price of VND 110,000/kg.

Khanh Hoa province

The main species being cultured in the 12,000 cages in the province was lobster as it was much more profitable than grouper.

A few grouper cages were observed near the river mouth to the south of Nha Trang where the salinity was too low to culture lobster. Although pony fish at VND 2000–5000/kg were sometimes fed when anchovy were not available, it was better to use anchovy at VND 3000–10,000/kg, depending on season, even though it was more expensive as grouper grew faster. Anchovy is a good feed for grouper if it is used fresh.

Mr Nguyen Van Thinh was interviewed. He started grouper culture in 1988. He raised grouper in failed shrimp ponds in which the growth rate was similar to that in cages, but the survival was higher and the management easier. He purchased 40–60 kg of trash fish daily, but if trash fish was insufficient then he used tilapia (*Oreochromis mossambicus*). He purchased trash fish daily at VND 1000–7000/kg; from March to August it was usually cheaper as the sea was calm. He purchased mixed species: anchovy, cardinal fish, pony fish, lizard fish as main species, but many other species in smaller amounts as well as small crabs and shrimps. He preferred to use anchovy as it was the best species for feed and in addition it could be fed to small grouper without the need to be chopped, which saved on labour. Anchovy was used for grouper <200 g but for larger sizes he used chopped cardinal, lizard, pony and rabbit fish. He did not feed grouper for 2–3 days each month at low tide. Nguyen Va Thinh said the price of trash fish had risen. It used to range from VND 500–1500/kg when it was abundant but the quantity declined and the price increased because of extra demand from grouper and lobster culture, gradually at first but markedly about three years ago. There are many more fishers and cage farmers at the present time and the interviewee was unsure if the total amount of trash fish had declined. However, it was more difficult for him to buy trash fish than previously. There was competition between use of anchovy for human food, fish sauce manufacture and fish feed. During Tet, when there was no fishing, the price rose very sharply. Some farmers used Grade 1 anchovy but Mr Thinh used Grade 2. He had never used Grade 3 anchovy because the most important criterion was freshness. He was also concerned about pond water quality from using Grade 3 anchovy.

Mr Thinh owned a 1.5 ha brackish water pond that received polluted water from the surrounding community and had overhung latrines. He hired a worker to look after his grouper ponds as well as to harvest tilapia. He harvested an average of 20 kg and sometimes 40 kg of tilapia a day, equivalent to at least 5 t/ha/year assuming a daily harvest rate of 20 kg. Another brackishwater tilapia pond of 1 ha was owned by Huynh Van Hai who claimed to harvest 10 t of tilapia annually. He harvested fish when there were buyers, 50–100 kg every 5–6 days (equivalent to 4.5–5.5 t/ha assuming harvest of 75 kg fish every 5–6 days). Tilapia production went down if he did not harvest frequently. Fish were harvested for human food and for grouper culture. Larger fish of 50–67 g (15–20 pieces/kg) were sold for human food at VND 8000–10,000/kg and smaller fish of 20–25 g (40–50 pieces/kg) were sold for cage culture at VND 5000–6000/kg. About 10–20 grouper farmers bought tilapia regularly, each purchasing amounts of 5–10 kg. When marine fish were abundant on the market Nguyen Van Thinh threw back the larger tilapia to wait for the September to December rainy season

when marine fish were scarce and the price of tilapia was higher. However, larger fish were harder to catch as they went into the mud. Tilapia were harvested using a 100 m long \times 1 m deep gill net from a boat, with fish driven into the net by beating the water.

Cage farming in Vung Me village at a large island in the sea opposite Nha Trang city started with the culture of grouper but mainly involved lobster as well as various kinds of marine fish (red grouper, black grouper, snapper), shrimp and ornamental fish. There were 2000 farms with an average of 20 cages per farm. Cage dimensions were $3 \times 3 \times 4$ m deep and 90% were stocked with lobster. Cages cost VND 2–3 million. Lobsters were fed once per day with trash fish, snails, clams and small crustacea on different days to maintain feeding as the lobsters would not consume the same feed on successive days. Trash fish was called “trawler fish” and comprised mixed anchovy, cardinal fish, clupeids, lizardfish and pony fish. It was delivered by boat by middlemen who bought it at the port. On arrival at the farm it was iced for the first time. About 100 trawlers from Binh Tan village and 180 trawlers from Nha Phu lagoon left about 4 pm in the evening and returned to port the following morning at about 4 am, sometimes earlier. The catch was landed and sorted and arrived at the cage site at about 9 am. Trash fish cost VND 4000–6000/kg, and were cheaper when the sea was calm. Presumably, the relatively high price was due to its freshness. Trash fish was still fairly abundant but there was less than before. The farmer interviewed with an average size farm used 40–100 kg trash fish per day depending on the size of the fish in the cages. When all of his 26 cages were full of fish the farmer fed them 100 kg per day. Golden snail, as well as two local species, were fed to lobster every three days. The farmer had 1300 lobsters from 300–600 g which consumed 70 kg snails (whole) at each feeding. Golden snail was purchased from middlemen for VND 3000/kg. The Golden snails were reported to be abundant in rice fields. Golden snail meat could also be fed to grouper but it was found to be labour-intensive to shuck them.

Mr Tam, a farmer culturing grouper in ponds, was interviewed in Cam Ranh district. There were about 20 farmers in his commune, Cam Thinh Dong. The area was previously mangrove and he was a fisher. He had been a fish farmer for 10 years and taught himself. Another farmer, Mr Truc, who used to farm shrimp in Ba Ngoi town, moved to the area and started shrimp farming in 1985 and others copied him from 1987. Mr Tam started aquaculture about eight years ago and also distributed grouper seed. He stocked one pond with grouper and two ponds with shrimp. Shrimp farming was more profitable than grouper but it was high risk because of disease, hence the culture of grouper. The main shrimp season was from March to July but during the rest of the year all ponds were used for grouper. Most farmers followed this system. A few farmers cultured two successive crops of shrimp, the most common system in the past, but it was very risky. However, they indicated that they now used a higher stocking density of *Penaeus monodon* of 20 PL_{10–12}/m² compared with 5–6/m² used previously so the growing period had increased from 3 to 4–5 months to harvest 40 pieces, sometimes 30 pieces/kg in a good crop. The farm gate price fluctuated but was now VND 102,000/kg. Shrimp were fed CP feed at VND 16,000–17,000/kg, even though local KP 90 feed was only VND 11,000–12,000/kg.

Mr Think distributed hatchery-raised grouper fingerlings from a Taiwanese company at VND 14,000/6–7 cm piece compared with only VND 10,000/piece of the same size from nature. The advantage was that farmers could buy a large number of grouper fingerlings from Mr Think and not have to wait until fishers could supply sufficient wild fingerlings. Ideal stocking density was 2–3/m² but some farmers stocked only 0.5–1/m² as they lacked funds. Grouper grew to at least 0.5 kg in 6–7 months, with a survival rate of 70%. Ponds ranged in size from 2000–4000 m² with a typical farm having three ponds. Tidal action was used to fill and drain ponds, but pumping was required to drain ponds completely as the bottom was 70 cm lower than low tide level.

Grouper were fed trash fish (cardinal fish, lizard fish, pony fish and small crustaceans) from the local fish landing port in Ba Ngoi town. Mr Thinh paid VND 700–5000/kg, depending on season and state of the sea. If the price was higher than VND 5000/kg he did not buy. Eight years ago the price of trash fish was only VND 300–400/kg. The price started to rise 4–5 years ago when lobster culture began. Middlemen also distributed trash fish on ice by motorcycle from Nha Trang and Phan Rang. Mr Thinh did not buy anchovy as it was too expensive at VND 10,000/kg.

The rate of feeding of trash fish was 80 kg/day for 2500 grouper of 400–500 g size stocked in a total of 9000 m² of ponds. There did not appear to be any alternative feeds to trash fish for grouper. The farm gate price for *E. malabaricus* of 1.5 kg was only VND 60,000/kg as they sold to middlemen for live export to China, compared with VND 100,000/kg in Nha Trang where fish were sold directly to the local restaurant trade.

Mr Thinh felt confident about the future, with few anticipated changes, although he thought there could be a trash fish supply problem if cage farming of lobster, which started in the area 7–8 years ago, expanded. He thought there was considerable potential for expansion of lobster cage culture if banks would give soft loans to farmers. Mr Thinh believed more farmers would invest in aquaculture if the price of produce increased although land for pond construction was limited. The local government did not allow the pond area to increase because of a concern about water quality.

A visit was made to Xuan Tu village, in Van Hung commune in Van Ninh district. Xuan Tu village is famous for cage lobster culture and about 600 households were involved in aquaculture, almost the entire village. Aquaculture had expanded rapidly in the commune with 2000 cages, mainly for lobster. About 10 households were raising grouper in cages and about five in 0.5 ha ponds. Households raising grouper lacked sufficient investment to culture lobster. Until recently, it was thought that the supply of wild seed would constrain lobster culture, but seed was abundant. However, for the first time in the year, lobster disease caused about 30% mortality. It was believed to have been caused by pollution of the bay bottom due to rapid expansion of cage culture and accumulation of organic matter. Two indicators of this were said to be the disappearance of the seaweed *Sargassum*, which normally was abundant in the rainy season, and the mortality of wild and also cultured snails. There were no institutional mechanisms to control the number of cages and entry was a free-for-all.

Lobster seed quality had also declined as seed became paralysed. Seed attracted by light and caught by net were weaker than those trapped in old fishing nets suspended from the surface of shallow seawater, as observed in Ninh Hoa district.

Another constraint was poaching. Mr Chim, the farmer interviewed, had lost VND 40 million from lobster poached from cages over the Tet holiday.

Culture of the sweet snail *Babylon* started about two years ago in Dai Lanh. *Babylon* snail were also fed trash fish, but only three farms remained from 100 farms last year because of almost 100% mortality from the polluted bottom of the bay. The species was a local one and was originally from Binh Thuan province where it grows wild in an upwelling area. Seed initially came from RIA No. 3 but the farmers learned how to farm it themselves. A local hatchery was also established as the farmers learned how to breed it.

About 4 t of trash fish were used daily by the commune all year round. The source was from trawlers based at Dai Lanh. About 60–70 households were involved as traders of mixed species of trash fish on ice. Price ranged from VND 3000–7000 with an average of VND 4000–5000/kg. There was still plenty of trash fish but the price had more or less doubled over the last three years from VND 1000–2500/kg. Mr Chim thought that trash fish numbers were declining. Even though the

number of farmers had increased, the number of trawlers had declined as fishing was not very economic. There were 100 trawlers three years ago but the number had declined to 30. Furthermore, over the last three years the length of the fishing trip increased from one night to between three and four nights. Trawlers were a standard size and caught 700–800 kg of trash fish as well as about 100 kg of higher value fish such as sea bream, pomfret and ribbon fish. Mr Chim thought that the future supply of trash fish would decline.

Now farmers had to use snails and oysters as well as trash fish, whereas three years ago they only used trash fish. About 300–400 kg of Golden snail was purchased from middlemen by the commune for VND 2000–2500/kg and was abundant all year round at a stable price. Children collected the snail from rice fields in Ninh Hoa district for VND 1000/kg. From 500 kg–1 t of freshwater pearl oyster was purchased daily from the Ninh Hoa river from VND 2500–6000/kg with an average of VND 4000/kg. The price varied because of the quality of the oysters; if they were broken they were cheaper as they had to be used immediately.

One farmer tried to feed lobster with pelleted feed purchased from a Hong Kong businessman, but it was not stable in water and expensive at VND 20,000/kg, although the lobster ate it and grew.

Chau Doc, An Giang province

The first key informant interviewed was Mr Tho whose family were pioneers in cage culture. They first started raising fish in cages in Vietnam in 1960, at the border at Quoc Thai. Previously the family lived in Cambodia but war forced them to go to Vietnam. Mr Tho's grandfather was the largest fish merchant in Phnom Penh and had the largest number of cages for holding fish. Cages in Cambodia were used for holding fish and not for aquaculture. Cage aquaculture only began in 1960 with a maximum production of 500 kg for the first farm. Caged production rose to 1.5 t by 1965 and to 12 t by 1967. Fish were fed only ca linh (small freshwater fish), snails and young maize. In 1965 there were only about 50 cages in Vietnam. The Vietnamese fishers were pioneers in cage culture and the Khmer copied. The Cham only worked for the Vietnamese.

The seed supply for cage culture in 1960, about 6 cm *P. bocourti* (basa), were caught by hook and line in Vietnam and Cambodia. A mesh size of 5 mm was used for the first cages. *P. hypophthalmus* (tra) was a latrine pond fish caught in the daytime and nursed in ponds. Fishers tried to nurse basa in ponds but failed. Dong Thap province was the area for traditional nursing of wild seed of tra, collected illegally by day in Cambodia and Vietnam before 1998. Mr Tho confirmed that hatchery-raised seed of tra was only ever stocked in cages. In Dong Thap province nursing was carried out only in ponds and not in cages. There were many small-scale hatcheries in Dong Thap, and many nursery farms <1 ha in area. The state hatchery in Dong Thap produced about 500 million hatchlings/year with a survival rate of about 30% to produce a 20 g fingerling. One private hatchery produced 100 million hatchlings/year. Initially egg yolk was used in nursing followed by rice bran, trash fish and fish meal and fish powder from Kien Giang, Can Tho and Da Nang provinces. Mr Tho was the only farmer nursing in ponds in Chau Doc as it required a high investment.

Mr Tho thought that the reason day fishing for fingerlings had stopped in Vietnam was because fishers would be imprisoned if caught. Fishing for fingerlings may still go on in Cambodia, but nurseries in Vietnam produce enough for the local market and export to Cambodia. From 1995–97, Mr Tho organised 2500 Vietnamese fishers to move to Cambodia to catch basa fingerlings until the Cambodian and Vietnamese governments banned the tra day fishery. Following the development of

hatcheries for *Pangasius* in 1998, artificial seed became cheaper than wild seed, so fisheries collecting wild seed closed down. All seed produced in Dong Thap today comes from hatcheries.

According to Mr Tho, the number of cages increased by 50% over the last two years. The number of cages by year is as follows: 1989 (300), 1995 (500), 1996 (700), 1997 (1000), 1998 (2000), 1999 (2500), 2000 (3000), 2001 (4000) and 2002 (6000). About 100,000 t of *Pangasius* was being produced in An Giang province in cages, with basa only contributing 1%. Production in the three major sites was Chau Doc and An Phu (40,000 t), Chau Phu, Phu Tan, Tan Chau and Cho Moi (30,000 t) and Long Xuyen (30,000 t). There were 14 processing plants. The farm gate price fell as low as D 8000/kg in 2000 because of insufficient processing capacity for farmed production, but this has been remedied.

Mr Tho used to produce 5000–6000 t/year, but since he went into the hatchery and feed distribution businesses he now produced only 1000 t of table fish. He raised both tra and basa in cages, although the latter species had a higher cost of production because it was harder to raise with a lower survival rate.

Mr Tho mainly produced tra in his hatchery as basa was difficult to breed. Basa fingerlings cost only VND 600/piece in 1989 but by 1995 had risen to VND 7000/piece with a maximum price for a 12 cm 40 g fingerling of VND 8000 in 1997. The current price for basa fingerling was VND 2500 compared to VND 800–1200 for a tra fingerling of 12 cm. The farm gate price for basa and tra were VND 14,000 and VND 10,000/kg respectively. Production costs for basa and tra with traditional feed were VND 13,000 and VND 9500, and with pelleted feed they were VND 13,000 and VND 10,000/kg respectively. The farm gate price was the same, irrespective of feed used. To get 1 kg of fillet required 4.2 kg of basa with traditional feed and 3.8 kg with pelleted feed; and 3.0 kg of tra with traditional feed and 2.8 kg with pelleted feed. Traditional feed resulted in a fish with more fat and less meat.

Only *Pangasius* were intentionally stocked in cages, but wild carp that entered through the lattice when small could not escape when they grew larger, and were harvested as part of the crop. Carp were not stocked because they consumed feed for *Pangasius*. During the flooding season, fingerlings of other valuable wild fish entered *Pangasius* cages and were caught by lift net and bamboo trap and stocked separately (these comprised <0.5% of the harvest): snakehead (VND 16,000/kg), ca do (VND 20,000/kg), ca leo (VND 25,000/kg), ca lang (VND 25,000/kg) and ca hu (VND 18,000–20,000/kg). A 600 m³ cage produced a harvest of 70 t or 117 kg fish/m³. Stocked fish grew from 20 g to 1 kg in eight months. All farmers more or less fed fish with rice bran and trash fish in a 7:3 ratio for the first six months and 6:4 in the last two months. Pumpkin and golden snail turned the fish flesh yellow. Duckweed has high protein, does not affect skin colour and although Mr Tho used to use it, it is only considered suitable for small-scale culture. Water spinach was used before 1995, when only basa was cultured, but it turns the flesh of tra yellow. Only 10% of cage farmers used pelleted feed as pellets cost VND 4000/kg compared with trash fish and rice bran at VND 2500/kg. 2 kg pelleted feed were equivalent to 2.5 kg moist feed. Only floating pellets were currently used, as recommended by Mr Tho, because there was less wastage compared with the sinking pellets originally used. In 1995 Mr Tho cooperated with CP Company on a feeding trial with catfish but it was not profitable. However, pellets produced better growth, required less labour and caused less pollution.

Mr Tho used to raise ducks from which he got the idea of using a piece of wood to bang on the feeding platform to attract the fish when feeding. He was also the first farmer to introduce the mincing machine in 1993. Other farmers said the noise would scare the fish but they are attracted by it during feeding. He copied the idea from a brick yard where extruders were used. The mincer is

a major improvement over feeding by hand, which took a long time. It was also difficult to control the cage workers who threw in large pieces of feed if they were tired, which was inefficient. All cage farmers in Chau Doc now used mincers for feeding fish.

Small wild fish (*ca linh*) were present in abundance outside cages feeding on waste food. About 1000 poor households made about VND 50,000 per night catching *ca linh* from small motorised boats with lift nets from beneath the cages when fish were being fed. They were sold for human food at VND 15,000–20,000/kg, a higher price than for *tra*.

Initially only fresh *ca linh* was used. From 1987 dried *ca linh* was ground using a Chinese machine. Dried anchovy was later ground to make fish powder. The availability of *ca linh* is much reduced because of overexploitation and the price has increased markedly. *Ca linh* cost VND 4000–10,000/kg in the flood season but VND 15,000–20,000/kg in the dry season, much more than *basa*. Marine trash fish was used since 1995, and recently it has been used entirely even though the price has risen. Ten years ago marine trash fish cost VND 50–150/kg but now VND 2800–4000/kg. Marine trash fish was expensive as well as high risk as it was not fresh. Marine trash fish was available all year round although the species composition changed seasonally. It was most expensive from October–December during the rainy season.

Mr Tho bred *tra* and *basa* at his hatchery, which consisted of Zug jars, concrete tanks and 24 ponds mostly of 400 m². The Zug jars were made of fibreglass and not glass as in the Hungarian type. Mr Tho bred *tra* all year round. From 45 million hatchlings in 1998, he expected to increase production to 350 million in 2003. This was the only large-scale hatchery in the province although there were four smaller hatcheries producing 50 million fry each. There was also a state hatchery in Dong Thap province. From 4000 female and 600 male broodstock, he selected 1200 female and 300 male broodstock. These produced 300 kg eggs which produced 350 million hatchlings. *Tra* started breeding at six years of age at 8 kg weight. Eggs were incubated for 18–24 hours in Zug jars depending on temperature, followed by 30 hours in a concrete rearing tank before being stocked in earthen ponds. Feed initially comprised boiled and finely ground duck egg yolk. After feeding in the pond with egg yolk for six days, fine Unipresident pelleted feed was fed for the next six days. For the next 12–18 days, the fry were fed with a larger pellet size and from the 15–18th day (500 fry/kg) were moved to a second farm. After another 30–35 days they had reached 15–20 g, after which there were three options. One was transferal to a third farm for pond nursing from 20–100 g using Unipresident and Proconco pelleted feed. A second option was to nurse in cages for another 45–50 days to produce 100 g fingerlings and a third option was to use directly for grow-out. It took 100 days from hatchling to 100 g fingerling. Mr Tho sold 30–40 million 15–20 g fingerlings for VND 500–700/piece and 5 million 100 g fingerlings (about 5% of the market) for VND 1000–1500/piece. Over 100 customers bought fingerlings from him. Mr Tho had broodstock cages and 40 nursing cages.

Mr Tho said that Vietnam could now compete with the USA as production costs were lower but the competitive advantage would be less in the future as the costs of ingredients rose. He was concerned about shortages of both trash fish and rice bran which would influence prices. He pointed out that it cost only VND 600 to produce 1 kg of catfish in 1989 compared with VND 8000 at the time of the interview (although the decline in the value of the Dong would need to be considered). He was worried about rice bran because the Government had set a ceiling on rice production as it was not so profitable. Compared with subsidised American farmers, Mr Tho could not borrow the US\$200,000 he wanted to invest, even though he had collateral, as it was complicated and the interest rate was high.

Looking ten years on, Mr Tho predicted that the domestic market, currently only 5% of catfish production, would increase. However, the trade conflict with the USA required resolution as before

the Tet holidays the farm gate price of catfish was VND 11,000/kg, but after intervention by the US Ministry of Trade it fell to VND 9000/kg for first grade fish which meant those farmers using pelleted feed were losing money. He thought it was feasible to produce the 200,000 t forecast by the Government as the carrying capacity of the river was high if factories were prohibited from discharging effluents into the river. Mr Tho said that leftover feed, <10%, did not pollute the river and was flushed out to the sea during the six months flooding season. In the dry season there was no problem with basa, only with tra concerning low dissolved oxygen.

He proposed the following research needs:

- ▶ Improvement of seed quality
- ▶ Improvement of feed quality
- ▶ Production of high quality fish with higher fillet content, lower fat content, improved colour and improved flavour
- ▶ Improved husbandry, especially feeding practice
- ▶ Increased fish resistance to environmental shocks and disease
- ▶ Market expansion as it is a healthy product
- ▶ Utilisation of fish processing by-products such as fish bile for medicine; fish stomach for direct human food; fish fat for cooking oil; and ground bones as powder as an ingredient for livestock feed in feed mills.

Fat now comprised 30% of the offal. “Basa” means three fat layers and is a fattier fish than tra.

Mr Tho had tried to culture tilapia several times but failed each time and lost money. Fish of 20 g size were stocked at 20/m³ in 96 m³ (4 × 8 × 3 m) and 150 m³ (5 × 10 × 3 m) cages. After the start of the rainy season fish died each day (this was also reported in the Mekong river in NE Thailand). Mr Tho had talked to Philippe Serene, and believed it was not feasible to culture red tilapia in cages in the river, for the following reasons:

- ▶ Silt in the rainy season
- ▶ High salinity and cool water during the high tide season from February–July
- ▶ Temperature change is not good for fish as they become more active, damage themselves and become more susceptible to disease.

Mr Tho had also failed with sea bass.

Long Xuyen, An Giang province

The second key informant on catfish cage culture was Phan Van Danh, the Vice-Director of the An Giang Fisheries Association. Mr Danh was a retired government officer but also a catfish farmer in ponds, pens and cages.

The total production from freshwater capture fisheries in An Giang province was said to be 50,000 t of which 30,000 t was ca linh (this official statistic is a gross underestimation as an MRC study indicated the amount was about 250,000 t). Many fish sauce factories used ca linh although its protein content is less than that of anchovy.

The total production of high quality catfish was 100,000 t (50,000 from cages, 40,000 from ponds and 10,000 t from pens) with a trend for an increase in pond and pen production. Although off-flavour occurred in ponds, fish cultured in ponds were less susceptible to disease and easier to treat.

Basa is to become the symbol of Chau Doc. Basa and tra were said to have more or less the same taste with some preferring the cheaper tra as it had a lower fat content. As well as a lower production cost, tra also had a higher dress out weight than basa, with 3.1 and 3.7–3.8 kg fish (respectively) required to produce 1 kg fillet.

Pen culture has been developed in Long Xuyen because of shallow water along the river, with lots of suitable sites for future development. There were 30 pen farms. Pen culture developed in 2002. Pens were cheaper to build than ponds and cages and fish had less disease. Mr Danh had three pens of 0.5 ha, stocked with 100,000 fish/pen. The cost of setting up three pens was D 200,000 compared to D 2 billion for cages, D 1 billion for a grow-out pond along the river bank and D 0.2–0.3 billion for a rice field for the same number of stocked fish.

Small cages were observed in the river, of a 300–500 kg capacity which produced catfish for the local market. About 4000–5000 small-scale households had family-level cages. The provincial government and the association tried to help households through provision of soft loans although foreign assistance was required to help poor farmers.

Mr Danh had been involved in aquaculture for more than 20 years. He currently raised hatchlings to 100 g in ponds, followed by grow-out in pens and cages. He obtained hatchlings from the provincial seed centre at VND 10/piece and stocked a 4000 m² pond with one million, with a survival rate of 40–80% in 4–5 months' growth. Hatchlings were fed algae (trung nuoc) for the first seven days, followed by egg yolk mixed with the flesh of small fish suitable for human consumption and cooked. For the next 10–15 days the smallest size pellets were used, followed by the next largest size of pelleted feed for a few more days. From the second month onwards, rice bran, soybean meal and trash fish were mixed at a 2:1:1 ratio, 2 kg vitamin C was added per t of mixed feed, and cooked.

The feeding strategy for grow-out was to reduce the protein content of the rice bran : trash fish : soybean cake ratio from 50% to 30% by using the following ratios: 100–500 g (2:1:1), 500–800 g (3:1:1) and >800 g (8:1:1). Although the same feeding ratios were used in pens and cages, growth was better in pens because of the large surface area providing plenty of air.

Only about 10–20% of fish farmers used pelleted feed because the price (approximately VND 4200/kg) was relatively high compared with traditional feed, although Phan Van Danh expected that the number of farmers using pelleted feed would gradually increase. In 1989 to 1990 the change from 100% use of small freshwater fish (ca linh) as feed to marine trash fish started. By 1994 to 1995 ca linh was no longer used to feed fish as expansion of rice fields had reduced its habitat for breeding. Ca linh also came from Cambodia in November and December and was used over 3–4 months. Limited dried ca linh was now sold for feed but account for only 1–2% of the total feed used.

The prices of trash fish and rice bran have doubled over the last two years. Trash fish now ranged from VND 2600–3200/kg with an average price of VND 2800/kg, compared with VND 1100–1900 before 1999. Rice bran now cost VND 1500–2500/kg with an average of VND 2200/kg compared with VND 900–1800/kg before 1999. The trash fish supply was adequate now but there was concern for the future when aquaculture production increases.

The present production of high quality catfish was 180,000 t (116,000 t from An Giang and the rest from Cantho, Vinh Long and Dong Thap). Five years from now the production is expected to be 250,000 t and 300,000–700,000 t in 10 years' time, depending on the market. Constraints to increased production in order of importance are market and then feed ingredients. Alternative ingredients are required as rice field production, and therefore rice bran, as well as trash have reached a ceiling.

In discussing research needs, Mr Danh pointed out the need to change from using trash fish to plant protein sources such as soybean. Incorporation of trash fish in pelleted feed leads to better utilisation compared with traditional feeding with trash fish. With lower inclusion rates of trash fish and use of alternative protein sources, limited trash fish would be more efficiently utilised.

Although catfish production is being intensified, with increasing utilisation of industrial based inputs that may put it beyond the reach of the poor, there is employment for the poor as labour in input supply, production, marketing and processing. One worker can take care of 30 t of fish in cages. From culture to final filleted product in a sealed plastic bag ready for export, it was estimated that one worker was required per tonne of fish.

The prospects for catfish production were considered to be good as the domestic market and export market were predicted to expand in the future. The trade dispute with the USA was considered to be good advertising for a low-price, high-value fish. Previously consumers in the USA were only aware of the price of catfish, not the difference in quality between channel catfish and tra and basa. Although Mr Danh was aware that Philippe Serene has 10 cage farms for red tilapia in Can Tho, he believed that Vietnam's comparative advantage is with catfish because of unique conditions and established markets. Other countries are producing red tilapia for export.

Pond culture in Chau Doc, An Giang province

A farmer was interviewed who cultured tra in four ponds with a total area of 0.8 ha. He sold 55 t of fish in the previous year, which took 7–8 months to reach marketable size of 1 kg, a harvest of almost 70 t/ha. About 20% of the 100,000 t of high quality catfish came from ponds with the remaining 80% from cages. Quality was acceptable as processing factories rejected fish with off-flavour. Fingerlings of 6–7 cm (10 g) were obtained from many hatcheries at VND 420/piece. In the previous year the farmer fed the fish with trash fish and rice bran at a ratio of 1:1. Last year trash fish cost VND 2500–3000/kg, but this year the price had risen to an average of VND 2700 and was sometimes VND 3500/kg. The farmer used 100–500 kg/day depending on the size of fish. As the price of trash fish was now too high he had switched to using shrimp head powder from Kien Giang province at VND 1400/kg. The same ratio of 1:1 with rice bran was used, which resulted in the same growth rate as before but if the farmer wanted to increase the growth rate he added more shrimp head powder. He also used to feed young maize shoots and maize grains which produced good growth, but their supply was limited. Golden snails were plentiful, but were used mainly to feed ducks. Fish survival in ponds was higher than in cages, 80% and 70%, respectively. There was little disease, but fish cultured at high density bruise each other. The two main problems were rising cost of feed and market. The interviewee called for research to produce feed that leads to a good growth rate with reasonable price. He sold tra last year for VND 12,200/kg, a reasonable price for filleting; this year, however, the price was only VND 6600/kg because of the trade dispute with the USA and he thought he would lose money. A third problem was obtaining a soft loan as only farmers in agriculture were able to do so, but not in aquaculture.

A nearby farmer had a 0.16 ha pond and sold 3.2 t of tra last year, a harvest of 20 t/ha. A middleman purchased the fish for sale at VND 10,000/kg for direct human consumption in Ho Chi Minh City. In the previous year trash fish cost VND 2000–2500/kg but this year the price had risen to VND 2500–3000/kg. Although there was plenty available, the price of trash fish was too high as the price of tra had fallen and only rice bran was being fed. The price of rice bran ranged from VND 1200–2600/kg in the previous year, to VND 1700–2400/kg in the current year.

A neighbouring small-scale farmer was raising tra and red tilapia in a 240 m² pond which was being fed duckweed at the rate of 4 kg per day, produced from an adjacent 0.25 ha pond. The large pond was fertilised with 2 kg urea/week, and never nightsoil which the lady farmer considered to be a dirty practice. She harvested 100 kg duckweed/day (equivalent to 7.3 t dry duckweed/ha/year). She sold 30 kg freshweight at VND 5000/sac. The year before the interview she had harvested 5 t of tra from the large pond, equivalent to 20 t/ha, but in the current year she had failed because of the trade dispute with the USA (the price of tra had fallen to VND 7000/kg or less).

Pond culture in Rach Gia, Kien Giang province

A farmer was visited, the only one in the locality, who was culturing tra and snakehead (ca loc bong, with hatchery produced seed from Chau Doc). He had 10 ponds with a total area of about 0.3 ha. Fish were fed with trash fish and fish processing wastes from a small-scale fish processing factory that dried fish. Fish processing wastes were transported to the farm in containers by motorbike. The farmer bought ray offal for VND 0.5 million/month, in two 30 L plastic containers/day. He also bought fish heads and fish skeletons, both for VND 1200/kg. Ray offal was observed being fed directly, as was the mixing of fish heads with ground kapok leaf powder as a binder which was minced before feeding to fish. Kapok powder imported from Cambodia cost VND 4000/kg. Trash fish was reported to be mixed with rice bran at a ratio of 1:6 and cooked before feeding. Pangasius and snakehead were sold on the local market for VND 9000–10,000 and VND 14,000/kg, respectively. A fish farmer friend of the interviewee had cultured red tilapia after reading a newspaper article stating that it sold for VND 20,000/kg, but lost money as he was only able to sell it locally for VND 8000–12,000/kg.

Vung Tau

We drove through a large area of abandoned shrimp ponds in a former mangrove forest in Ben Xuc. Industrial intensive shrimp culture using pelleted feed started in 1988 but failed due to white spot disease in 2002. The shrimp culture may have collapsed because of stress caused by low pH as the area was some distance from the sea and seawater could not be used to flush out the acid.

Mr Hau, a farmer in An Ngai commune, had been farming shrimp for three crops. Although he had just harvested 2 t of shrimp from another pond, two months ago he stocked grouper in a higher salinity pond in which the previous shrimp crop had been infected with white spot disease. Grouper seed of 5–7 cm were purchased at VND 15,000 each from a company in Vung Tau that imported them from Taiwan. Grouper seed could be obtained in Vietnam from four sources.

1. Local wild seed
2. Local hatchery produced seed, for example a Taiwanese company based in Van Ninh, Khanh Hoa province
3. Eggs imported from Taiwan and hatched in Vietnam
4. Fingerlings imported from Taiwan

Mr Hau fed grouper with 44–45 kg trash fish once a day on 22 feeding trays suspended in the 0.54 ha pond. Clupeid fish were used initially but were too expensive as the price had risen from VND 3000 to VND 4000/kg. Now Mr Hau used ca cang (Arrow bass) *Therapon jarbua* at VND 2000–2500/kg which was purchased at 40–80 g, 12–15 cm, and was chopped before feeding to fish. Trash fish was abundant at Long Hai landing port, 6 km away. One other farmer had started to raise grouper, although some farmers were also raising snakehead which required trash fish.

A competing use of trash fish was for traditional small-scale pig rearing — large-scale pig farming used formulated feed. Mr Hau expected trash fish to still be abundant in 10 years' time but he was unsure about the price. He expected to be able to sell 100–200 kg of 0.5–1 kg of grouper to restaurants in Vung Tau and Ho Chi Minh City for VND 80,000/kg.

Cage culture of grouper occurred also at Long Son but no visit took place. Two Taiwanese farmers used 200 cages to culture mainly cobia, as well as grouper, pomfret and sea eel. Seed was imported from Taiwan.

Vung Tau city discharged its wastewater through one main canal that eventually ran into the sea. Some years ago, Anders Dalsgaard reported wastewater-fed aquaculture in ponds alongside what was then an open wastewater canal. However, the canal had been covered over and most of the ponds filled in and built upon through rapid expansion of the city. The former RIA No. 2 *Macrobrachium* farm, which had been returned to the Government, appeared to be being used for wastewater-fed aquaculture as the ponds had dark green water and the larval rearing tanks were derelict. A large sedimentation lagoon was divided up by 62 farming households into pens with an average area of 2000 m². Since 1992 the local authority allowed migrants from the north and other parts of the country to raise fish in pens since 1992. Farmers were raising tra, tilapia, rohu and grass carp on rice bran and wastefood collected from restaurants and hotels. Farmers collected the waste food daily by bicycle and paid VND 60–70/20 L per container full. Farmers reported no problems raising fish in the wastewater-fed lagoon except for some disease in tilapia, grass carp and rohu in the wet season.

It would not be feasible to use the wastewater to culture tilapia as trash fish in Vung Tau as observed in Nha Trang because the wastewater canal was in an area undergoing rapid urbanisation. However, it may be feasible to use septage from vacuum trucks in Vung Tau to raise tilapia as trash fish in the large area of abandoned shrimp ponds in Ben Xuc. The concept was explained to Mr Hau, the grouper farmer, who said he would try it as only 2.5 ha of his more than 20 ha farm were being used.

14. General conclusions

- ▶ The total marine fish catch in Vietnam continues to rise, as well as the proportion of the biomass of trash fish in the total catch. This is due to over-fishing. However, the quality of trash fish is usually poor because of inadequate preservation on board ship.
- ▶ There has been a dramatic recent rise in the use of trash fish in aquaculture with the development of marine cage culture of grouper and lobster, and the expansion of freshwater culture of river catfish in cages, ponds and pens.
- ▶ The availability of trash fish as a direct feed is likely to restrict the future expansion of aquaculture as supplies are finite, as indicated by a recent doubling of the price of trash fish.
- ▶ There are conflicting uses for trash fish for livestock feed, fish sauce and direct human food as well as for a direct aquaculture feed and fish meal manufacture in some areas. Traditional small-scale pig rearing uses trash fish but large-scale pig farming uses agro-industrial formulated feed containing fish meal. The national demand for fish sauce is predicted to double over the next decade. Some species previously considered as trash fish are now being used as human food fish because of developments in processing technology.
- ▶ Fish powder produced in a traditional artisanal way by sun drying and grinding is mainly used to feed livestock.
- ▶ Fish meal produced domestically, using an industrial process in which raw materials are cooked before being dried, is mostly of poor quality because trash fish is degraded by the time it reaches the fish meal plant. It is used by feed mills to produce feed for livestock and some grow-out feed for freshwater fish.
- ▶ Fish offal from processing may be used in fish meal manufacture when trash fish is in short supply, but it can only be used up to 5–20% of total ingredients as its protein content is too low and its ash/calcium content too high.
- ▶ At least 90% of fish meal is imported to meet the rapidly growing demand caused mainly by the development of aquaculture. Fish oil is not produced locally in industrial fish meal production and is also imported. Future demand for fish meal is expected to increase dramatically as an ingredient in industrial aqua feeds.
- ▶ As the prospects for increased production of quality fish meal (and fish oil) do not look promising, the future development of Vietnamese aquaculture will be strongly influenced by the availability and price of fish meal (and fish oil) on the international market.
- ▶ Although high value marine species such as grouper, lobster and shrimp may be able to compete for fish meal on the international market, this is unlikely to be the case for freshwater river catfish and tilapia. The latter will need to be fed increasing amounts of plant-based proteins, including possibly defatted rice bran.

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16. Appendices

16.1 Appendix 1 — Terms of Reference

- A. To conduct a survey of low-value, marine fish (“trash fish”) and fish meal used as aquaculture feed ingredients in Vietnam (ACIAR Contract No. C2002/067) by describing the production, uses and trends of trash fish, fish meal and fish oil in Vietnam. The following questions will be specifically addressed:**

Describe the production, uses and trends of trash fish in Vietnam

1. What species comprise marine “trash fish” used as an aquaculture feed or aquaculture feed ingredient in Vietnam?
2. How much trash fish is used in the aquaculture industry in Vietnam?
3. By how much has usage increased over the last decade and what are the likely future trends?
4. How are trash fish caught and processed?
5. What is the current price of trash fish and likely future price movements?
6. Does the use of the species that comprise “trash fish” impact on other uses, for example for direct human consumption or feed for other animals?
7. Is trash fish captured in Vietnamese waters exported to other countries?
8. Is trash fish imported into Vietnam from other countries and, if so, which ones and how much is imported?
9. Will availability of trash fish restrict future expansion of aquaculture in Vietnam and, if so, what species are likely to be most affected?

Describe the production, uses and trends of fish meal and fish oil in Vietnam

1. How much dried fish meal and/or fish oil is produced in Vietnam and what are the recent trends and future predictions in production?
2. What species are used for fish meal/fish oil production in Vietnam and what is the composition and nutritional value?
3. What species (aquaculture and other animals) are fed diets containing the fish meal/fish oil and is the fish meal used for other purposes, for example for fertiliser.
4. What is the wholesale price of the dried meal and fish oil?
5. What type of fish meal plants are used, what is the production capacity of the plants and how much raw fish is required?
6. Is any of the fish meal produced in Vietnam exported to other countries and, if so, how much?
7. How much dried fish meal is imported into Vietnam, where is it from and how much does it cost?

- B. In collaboration with the Vietnamese specialist (Dr Le Anh Tuan), to prepare and submit a report summarising the above information.**

Methods:

Desk top survey, interviews and field visits will be used to address the terms of reference and provide data on the following:

Trash fish

1. Species composition (by region if there are differences)
2. Volume landed and percentage used in aquaculture (include changes over the last decade and predicted future trends)
3. Capture methods and processing methods (if any)
4. Current price and past and predicted future price fluctuations
5. Exports and imports (volume, price, species, source or destination)
6. Impact of aquaculture use of trash fish on other uses, for example for human food or feed for other animals
7. Will future availability or price of trash fish impact on aquaculture development?

Fish meal/fishoil

1. Is there any fish meal/fish oil production in Vietnam?
2. Species composition
3. Volume produced and percentage used in aquaculture (include changes over the last decade and predicted future trends)
4. Capture methods and type of fish meal/fishoil plant
5. Current price and past and predicted future price fluctuations
6. Exports and imports (volume, price, species, source or destination)
7. Impact of aquaculture use of fish meal/fishoil on other uses, for example for human food or feed for other animals
8. Will future availability or price of fish meal/fishoil impact on aquaculture development?

16.2 Appendix 2 — Itinerary and persons interviewed

Sunday 9 February

- ▶ travelled to Hanoi
- ▶ discussed program with Phan Thi Van, Head of Environmental Department, RIA No. 1

Monday 10 February

- ▶ morning appointment with Ministry of Fisheries postponed and, of necessity, subsequently cancelled
- ▶ travelled to Hai Phong
- ▶ discussions with staff of Research Institute for Marine Fisheries (RIMF): Dr Chu Tien Vinh, Deputy Director; Nguyen Viet Nghia, Deputy Head, Department of Marine Living Resources; Dr Nguyen Van Le, Chief, Post Harvest Research Department; Dr Vu Dung, Director, Centre for Brackishwater Fisheries Research, RIA No. 1 (based at RIMF)

- ▶ Dr Sten Christensen, Senior Scientist, Department of Marine Fisheries, Danish Institute for Fisheries Research (CTA of Phase I, Danida funded project Assessment of Living Marine Resources of Vietnam, ALMRV)
- ▶ Pham Van Thanh, Vice Director of Department of Planning and Investment, MOFI (retired 3 years ago)

Tuesday 11 February

- ▶ Dr Do Van Khuong, Director (RIMF)
- ▶ Dr Le Xan, Vice Director, RIA No. 1 (based at RIMF)
- ▶ Cat Ba market, Hai Phong
- ▶ Cat Ba fish landing port
- ▶ Cat Ba Marine Broodstock Centre, RIA No. 1
- ▶ Fish cages, RIA No. 1
- ▶ Small-scale cage farmer
- ▶ Fisherman

Wednesday 12 February

- ▶ Beach fish landing, Do Son
- ▶ Center for Brackishwater Fisheries Research; Dr Vu Dung, Director; Mai Kong Khue, Vice Director; Mr Quyen, Aquaculture Specialist
- ▶ Do Son shrimp farmer
- ▶ Do Son fish landing port

Thursday 13 February

- ▶ travelled to Nha Trang
- ▶ discussions with faculty of University of Fisheries: Dr Nguyen Dinh Mao; Dr Hoang Tung
- ▶ grouper farmer, Nguyen Lean Think

Friday 14 February

- ▶ Vinh Tuong fish landing port, Nha Trang
- ▶ lobster cage culture, Vunh Me village Nha Trang
- ▶ wastewater-fed tilapia ponds, Huynh Van Hai and Nguyen Lean Think
- ▶ Van Loi fish sauce factory, Nha Trang
- ▶ grouper pond farm Mr Truc, Cam Ranh

Saturday 15 February

- ▶ Cu Lao fish landing port, Nha Trang
- ▶ Tan Thanh fishing village, Ninh Hoa
- ▶ Asia Hawai Venture, Phu Yen (feed mill-shrimp farm; denied access)
- ▶ lobster cage culture, Van Ninh

Sunday 16 February

- ▶ travelled from Nha Trang to Chau Doc
- ▶ dinner with *Pangasius* farmer Nguyen Van Tho and his daughter Nguyen Thuy Trang

Monday 17 February

- ▶ fingerling ponds and grow-out cages of *Pangasius*, Chau Doc
- ▶ small-scale *Pangasius* grow-out in ponds, Chau Doc
- ▶ large-scale *Pangasius* grow-out in ponds, Chau Doc
- ▶ travelled from Chau Doc to Rach Gia

Tuesday 18 February

- ▶ main fish landing port, Rach Gia, interviewed a fishing trawler owner and a fish trader
- ▶ small fish landing port, Nam Phuong, interviewed a fish trader
- ▶ Nam Phuong Fish Sauce Company
- ▶ Kisimex Fish Meal Factory (Le Anh Tuan allowed to visit but Peter Edwards denied access)
- ▶ freshwater fish ponds, Rach Gia
- ▶ small-scale fish processing factories, Rach Gia (accompanied by Cao Van Thong, Rach Gia provincial aquaculture extensionist)

Wednesday 19 February

- ▶ Phan Van Danh, Vice Director, An Giang Fisheries Association, Long Xuyen
- ▶ pen culture of *Pangasius*, Long Xuyen
- ▶ lunch with Pham Van Dung, Member, Tran Phu Huu, Secretary of Phan Van Danh, Vice Director of An Giang Fisheries Association
- ▶ *Pangasius* filleting factory, unable to visit
- ▶ travelled to Ho Chi Minh City

Thursday 20 and Friday 21 February

- ▶ attended Periurban Aquatic Production Systems workshop

Saturday 22 February

- ▶ travelled to Vung Tau

Sunday 23 February

- ▶ Vung Tau fish landing port, Ben Da, interviewed a fisherman and a fish trader
- ▶ small-scale fish processing, Sao Mai
- ▶ grouper farm, Mr Hau, An Ngai commune (accompanied by Phan Van Manh, private shrimp hatchery owner and 1993 UoF graduate)

Monday 24 February

- ▶ Nguyen Quoc Hung, Director, Vung Tau Research Center for Shrimp, RIA No. 2
- ▶ returned to Ho Chi Minh City
- ▶ dinner with Dr Nguyen Hao, Director, RIA No. 2 and Nguyen Thi Quang Thuy, feed processing for fish and shrimp

Tuesday 25 February

- ▶ Philippe Serene, Aqua service, Ho Chi Minh City
- ▶ Dr Le Thanh Hung, University of Agriculture and Forestry, Tu Duc, Ho Chi Minh City
- ▶ Bach Thi Quynh Mai and Nguyen Thi Quang Thuy, feed processing for fish and shrimp, RIA No. 2

Wednesday 26 February

- ▶ returned to Bangkok (PE) and Nha Trang (LAT)

16.3 Appendix 3 — Summary of Danida funded study on fish meal and oil production in Vietnam (NIRAS, 2001).

- ▶ No statistics on the amount of trash fish landed or used by fish meal plants.
- ▶ A fishing fleet was reported to have been established at Cat Lo near Vung Tau with trash fish as its main target as this is more financially beneficial than trawling for more valuable species with trash fish as a by-catch (NIRAS, 2001).
- ▶ Trash fish is used for purposes other than making fish meal, which usually command higher prices in terms of sales price per unit of trash fish. Because of this there is a shortage of trash fish available for fish meal production. This situation is unlikely to improve and may worsen due to:
 - ▶ continued overfishing
 - ▶ regulations to protect juveniles
 - ▶ increasing demand for fish sauce
 - ▶ increasing demand for fish for direct human consumption.
- ▶ The Government needs to pay attention to use of trash fish for national food security, especially for the poor (NIRAS, 2001).
- ▶ We visited five fish meal plants out of 15–20 in operation although some may produce fish powder by grinding dried raw material and not use an industrial processing technology.
- ▶ Total production of fish meal was estimated to be about 80,000 t annually with a capacity of 100,000–130,000 t. Production of fish powder was estimated to be about 185,000 t.
- ▶ The five factories visited used cooking-drying technology with a screw cooker in series with a number of screw “coolers” (driers) to adjust the dry matter content of the final product. Oil was not separated which could result in high fat content in the meal, especially using pelagic species, which would require treatment with antioxidants to avoid the risk of oxidation. As attention in marketing was given to protein content, too high evaporation in the drier units used to increase the crude protein content could risk browning the meal and reducing protein digestibility.

- ▶ Offal from 5–20% was used at times because of a shortage of trash fish, leading to higher ash levels in the meal.
- ▶ Feed mills in Vietnam typically use domestic fish meal for production of livestock feed because of low protein content. Little domestic fish meal is used to manufacture feed for fish and crustaceans.
- ▶ Future demand for fish meal is expected to increase due to:
 - ▶ an expanding aquaculture industry
 - ▶ poor water quality in culture using home-made wet or semi-moist feed based on raw fish and/or fish and crustacean by-products.
- ▶ Competition for trash fish between:
 - ▶ fish meal
 - ▶ fish powder
 - ▶ fish sauce
 - ▶ direct human food for poor people and ethnic minorities.
- ▶ The amount of raw material may increase significantly from fish and crustacean by-products from an expanding fish and seafood industry.
- ▶ Without technological improvements in the current domestic production of fish meal, it may be used only in livestock and inland fish feed which can use lower quality fish meal.
- ▶ Shrimp peeling waste is not a desirable raw material for fish meal manufacture due to low protein content and rapid degradation. Some is sun-dried and exported to China for production of chitin/chitosan.
- ▶ Freshwater catfish processing waste is not a desirable raw material for fish meal manufacture because of a very high fat content that is not easily processed without fat (liquid) separation.
- ▶ High quality fish meal cannot be manufactured from processing degraded trash fish. Proper preservation with ice and short transportation are essential. However, Vietnamese fishing boats usually lack insulated storage facilities and therefore cannot carry enough ice to preserve all the catch during long trips. Thus, trash fish may be thrown back into the sea or transported ashore with little to no ice. Grading fish on the ground at the port into edible and trash fish accelerates degradation.
- ▶ It was concluded that:
 - ▶ trash fish for fish meal production is scarce
 - ▶ the price of fish meal is close to or higher than fish meal production can justify.
 - ▶ the quality of trash fish is usually not good, which limits the quality of fish meal that can be manufactured.
- ▶ Plans for building new fish meal plants in many provinces — either as additional capacity or as replacement for older technology.
- ▶ The main reason for not utilising the full capacity of existing fish meal plants was limited or expensive trash fish.
- ▶ Although the main trash fish species are demersal, pelagic fish are used when landings exceed both direct human consumption needs and industrial processing capacity.
- ▶ Most of the fish meal factories are in the south with only two active plants in the north and one or two in the centre of the country.

- ▶ Offal from inland catfish is utilised for production of fish meal and the quantities are increasing.
- ▶ Offal cannot be used alone for fish meal production because the protein content would be too low and the ash/calcium content too high.
- ▶ Feed mills interviewed expressed a willingness to buy more Vietnamese fish meal if the quality improved, but they indicated that this would be difficult to achieve because of both the quality of the raw material and the technology used.
- ▶ There is a need for fish meal factories to use more complex technology with pressing, separation of oil and dry matter in the stick water, evaporation and returning the protein pressed out of the cooked raw material. This would produce fish oil as well as fish meal of a high protein content without risk of browning the meal.
- ▶ Introduction of new technology into Vietnam may not lead to production of high quality fish meal that could compete with imported meal. A more capital intensive fish meal plant would have a higher rate of depreciation with an increased production cost. Furthermore, to produce a unit of fish meal with new technology would require more raw material compared with cooking and drying only, which would be a problem considering issues of supply and price of trash fish. Low capacity utilisation becomes even more expensive with a more capital intensive fish meal plant.
- ▶ If, in the future, landings of trash fish increase in excess of what could be used for other purposes then the price of trash fish would fall. This would increase the current narrow margin of profit for fish meal production and make investment in the sector attractive. The proposed increase in the off-shore fleet could lead to increased landings of trash fish, especially if it fails to reduce over-fishing in inshore waters. However, if the price of trash fish increases, the existing fish meal factories would not be financially viable.
- ▶ More than 250 enterprises produce seafood products today in Vietnam and continuous expansion will significantly increase waste or by-products. Some is used to produce low-value human food but the local market probably could not absorb a continued increase in waste.
- ▶ Kisimex in Kien Giang province started fish meal production in 1990 and up to 1994 it was exported to Japan and Taiwan. Since 1994 Kisimex has not exported fish meal directly because of high domestic demand, although one customer was reported to have exported some to China.
- ▶ To improve the quality of trash fish to contribute towards production of higher quality fish meal would require a major investment in infrastructure which could not be justified with the current market.
- ▶ Fish meal plants in Vietnam typically lack the following equipment needed to separate water and oil (fat) released during the cooking process: a press or a two or three phase decanter, one or two separators (centrifuges) and an evaporator. Typical equipment consists of cookers/driers in series, a shredder or screw conveyor for disintegration of the cooked/dried material, a hammer mill and bagging unit. Kisimex in Kien Giang province, however, operated a press and two other plants had equipment for mechanical separation of water and oil.
- ▶ Offal from freshwater catfish was initially only used for human consumption at a higher price than could be paid for fish meal production. With growing quantities and poor quality offal unfit for human consumption after transportation, there is scope for establishing a specialised fish meal factory based on freshwater fish and by-products in An Giang.

- Freshwater catfish offal is cooked, with separation of oil and the residue used to make fish sauce. The oil is sold to minorities and to Cambodia for human consumption and to feed mills producing livestock feed.

Table 8. Trash fish seasonal availability by region and species. (Main season, solid line; auxiliary season, broken line.)

North Vietnam												
Species	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Goat fish (<i>Upeneus</i>)				_____								
Lizard fish (<i>Saurida</i>)				_____								
Bullseye				_____								
Large-yellow croakers				_____								
Moustached thrysa	----	----	----	_____								
Commersonis anchovy (<i>Stolephorus</i>)	----	----	----	_____								
Trash fish sp.	----	----	----	_____								
Bombay-duck	----	----	----	_____								
Paste shrimp	----	----	----	_____								
Cat tiger				_____								_____
White shrimp				_____								_____
Central Vietnam												
Shrimp	----	----	----	_____								----
Commersonis anchovy (<i>Stolephorus</i>)	----	----	----	_____								----
Round scads (<i>Decapterus</i>)	----	----	----	_____								----
Sardine	----	----	----	_____								----
Goat fish (<i>Upeneus</i>)				----	----	----	_____					
Lizard fish (<i>Saurida</i>)				----	----	----	_____					
Large-yellow croakers				----	----	----	_____					
Hair tail (<i>Trichiurus</i>)				----	----	----	_____					
South Vietnam												
Shrimp				_____								_____
Large-yellow croakers				_____								_____
Trash fish sp.				_____								_____
Goat fish (<i>Upeneus</i>)				_____								_____
Lizard fish (<i>Saurida</i>)				_____								_____

Source: NIRAS (2001).