1. Assessment of aquaculture production with special reference to Asia and Europe

This section presents an overall assessment of aquaculture products and their production with special reference to the two regions, Asia and Europe. Production volume, product quality and price, production patterns (species diversification) as well as consumption patterns are discussed.

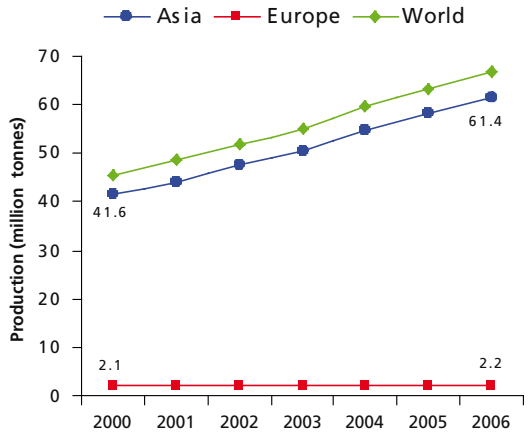
1.1 RECENT TRENDS IN AQUACULTURE PRODUCTION

1.1.1 Regional contribution to global production and implications for the aquafeed supply

Approximately 220 species of aquatic animals and plants are currently cultured worldwide, in a vast range of production systems, ranging from low-input extensive systems to high-input intensive aquafarms in ponds, caged enclosures and tanks. In broad terms, aquaculture production systems used for producing these aquatic animals and plants can be divided into feed-dependent systems or fed aquaculture (e.g. finfish and crustaceans) or non-fed aquaculture systems where culture is predominately dependent on the natural environment for food, e.g. aquatic plants and molluscs.

In 2006, global aquaculture production reached 66.7 million tonnes, growing at an annual rate of 9 percent, while increasing its proportional contribution to total fisheries output. Excluding aquatic plants, aquaculture output in 1970 accounted for 3.9 percent of total fisheries production, by 2001 that proportion had increased to 29 percent and by 2006 to 36 percent (FAO, 2008a). Thus, aquaculture continues to make a significant contribution to total fisheries production over the last few decades. This increasing contribution, however, is largely an Asian phenomenon because Asia accounted for 61.43 million tonnes or 92 percent of total world aquaculture production in 2006, while Europe contributed 2.17 million tonnes or 2.2 percent (Figure 1). In terms of value, the Asian region's share was US$68.61 million or 80 percent of total value of world aquaculture production. The Asian contribution is significantly influenced and skewed by China. When China is excluded, the Asian contribution to total world aquaculture production drops dramatically to 24.2 percent in terms of quantity and 29 percent in terms of value. As is evident, currently, aquaculture production is overwhelmingly concentrated in one country, China. Considering the geographic spread and potential economic contribution of aquaculture in relation to aquafeeds, a better assessment may be made by excluding Chinese fish and aquatic plants to understand the progress made by the other 105 countries that have reported aquaculture production of over 1 000 tonnes in 2006.

FIGURE 1
Recent trends in aquaculture production (including aquatic plants)



Source: Adapted from FAO (2008a).

When aquatic plants are excluded from production estimates for the Asian region and Asia

excluding China, aquaculture production contributes 90 percent and 23.2 percent, respectively, in terms of quantity and 78 percent and 29.2 percent in terms of value, respectively, to the world total aquaculture production. Aquatic plant production is dominated by China. Seventy-three percent of total aquatic plant production in Asia is in China. There is no noticeable change in terms of quantity or value of aquaculture in Europe when plants are excluded.

In Asia, fed aquaculture accounted for 54 percent of the region's total aquaculture production, indicating that almost half of Asia's aquaculture production comes from non-fed aquaculture. However, the non-fed aquaculture production within Asia is not evenly distributed and is mainly centred in China. Fifty percent of China's total aquaculture production (including plants) is non-fed aquaculture production.

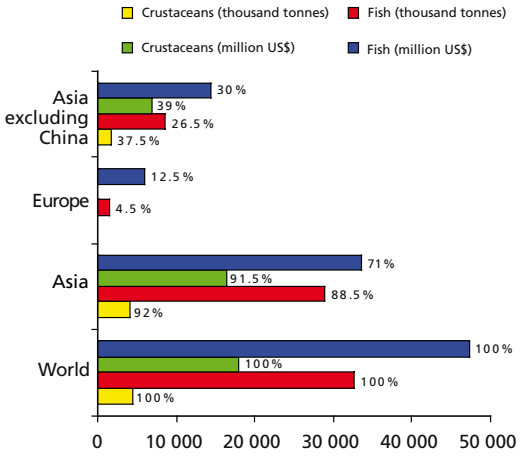
Asia's fed aquaculture, excluding China and including aquatic plants, amounts to 64.2 percent. If the recent trend in the slowing down of the annual growth of the non-fed aquaculture sector continues (see section below), while maintaining an increase in total aquaculture production, the demand for aquafeed in Asia will significantly increase. In contrast to the Asian situation, finfish and crustacean aquaculture production in Europe is 100 percent dependent on aquafeeds.

Asia's aquaculture production is also dominated by the use of aquafeeds. Asia is the largest global consumer of aquafeed ingredients. Aquaculture production, mainly of crustaceans and finfish, relies on farm-made or complete industrial diets. It is estimated that Asia contributed 88.5 percent of fish in terms of quantity and 71 percent in terms of value to total world fed aquaculture production (Figure 2). In contrast, Europe contributed 4.5 percent of fish in terms of quantity to total world fed aquaculture production. More importantly, Asia, excluding China, contributed 26.5 percent of fish in terms of quantity and 30 percent in terms of value to total world fed aquaculture production, indicating that the demand for aquafeed ingredients is also heavily skewed towards China.

In terms of crustacean fed aquaculture production, Asia contributed 91.5 percent of total world production (Figure 2). When China is excluded from the Asian equation, the contribution of the rest of Asia is 37.5 percent of total world crustacean production. Europe's contribution to world farmed crustacean production is negligible. Therefore, the impact of commodity volatility will be felt to a greater degree in Asia than in Europe.

Future pressure on the demand for feed ingredients will depend on the changing proportions of fed and non-fed aquaculture to total aquaculture production, the demand and the types of species used to meet the demand of aquatic products. The demand for feed ingredients will also depend on whether the trend will be to increase mass production of low-value species using aquafeeds or to increase production in high-value species, which generally requires high quality performance diets. Either way, the demand for all aquafeed ingredients will increase. Production of high-value species will put upward pressure on fishmeal and fish oil demand and prices, while production of low-value species will increase the demand and price for feed ingredients such as grains and oils of plant origin.

FIGURE 2
Contribution of Asia and Europe to world fed aquaculture by type of cultures



Source: Adapted from FAO (2008a).

1.1.2 Aquaculture growth in Asia and Europe

All aquaculture species groups have shown positive growth, but the acceleration in growth

has varied between species groups. Crustacean production grew at an average annual rate of 24.5 percent, while that of finfish and molluscs grew at an average growth of 7.0 percent and 5.0 percent, respectively, over the period 2000–2006. However, in the last three reporting years, the annual growth of crustacean aquaculture production has declined and stabilized at 9–12 percent. All other species groups, namely, amphibian, other invertebrates and aquatic plants showed a slowing down in their percentage annual production growth during the same period (Table 1). Thus, crustaceans and finfish are the groups that showed promising growth. As these species groups represent fed aquaculture, this will put greater upward pressure for farm-made or complete commercial diets.

The growth of fed aquaculture production in the Asian region has continued to be strong especially for the marine sector, reflecting a trend over the last ten years. This growth results mainly from a continuous increase in production in China. Between 2000 and 2006, production of fed aquaculture in China increased by 6.8 million tonnes (7.1 percent annual average growth). In terms of tonnage, other Asian countries that showed large increases included Myanmar, Viet Nam, Thailand, Indonesia, India and the Philippines over the same period (Table 2). Both freshwater and marine fed aquaculture (including brackish water) production showed a steady growth in leading aquaculture producing countries in Asia except in Japan. Out of the ten leading aquaculture producing countries, which contributed 87.1 percent to regional total fed aquaculture in Asia in 2006, Myanmar (185 percent), Viet Nam (68.4 percent), China (29 percent), and Taiwan Province of China (8 percent) showed a significantly higher average percentage annual growths in terms of quantity in the marine sector (including brackishwater) than in the freshwater sector over the same period (Table 2). Overall, Myanmar and Viet Nam are emerging as countries with substantial aquaculture growth in both environments (Table 2).

Just as China is the centre of production in Asia, Norway is the centre of fed aquaculture production in Europe, with an average annual percentage growth of 7.3 percent from 2000 to 2006 (Table 3). In 2006, Norway contributed 48 percent

TABLE 1
Global aquaculture production – percentage growth rates of different species groups

Species groups	2000–2006	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006
Amphibians	33	22	2	92	6	12	4
Crustaceans	24	17	12	36	12	9	12
Other invertebrates	48	17	-27	188	37	21	-4
Molluscs	5	6	6	4	4	3	5
Finfish	7	7	6	3	8	6	7
Aquatic plants	8	4	9	8	11	6	2

Source: FAO (2008a).

TABLE 2
Production of fed aquaculture in the top ten producing countries in Asia

Country	2000 production (thousand tonnes)			2006 production (thousand tonnes)			Average annual growth (%)		
	Total	Freshwater	Marine	Total	Freshwater	Marine	Total	Freshwater	Marine
China	15 881	15 077	804	22 650	20 445	2205	7.1	6.0	29.0
India	1 941	1 844	97	3 123	2973	150	10.2	10.2	9.2
Viet Nam	459	365	94	1 512	1034	478	38.3	30.6	68.4
Indonesia	789	363	426	1 293	664	629	10.7	13.8	8.0
Thailand	589	270	319	1 021	502	519	12.2	14.4	10.4
Bangladesh	657	570	87	892	785	107	6.0	6.0	4.0
Philippines	363	112	251	587	245	342	10.0	20.0	6.1
Myanmar	99	94	5	575	515	60	80.0	75.0	185.0
Japan	321	60	261	302	42	260	-1.0	-5.2	0.0
Taiwan Province of China	179	131	48	217	145	72	3.5	1.7	8.4

Source: FAO (2008a).

TABLE 3
Production of fed aquaculture in the top ten producing countries in Europe

Country	2000 production (thousand tonnes)			2006 production (thousand tonnes)			Average annual growth (%)		
	Total	Freshwater	Marine	Total	Freshwater	Marine	Total	Freshwater	Marine
Norway	490	–	490	705	–	705	7.3	–	7.3
United Kingdom	140	10	130	146	11	135	0.7	1.6	0.6
Russian Federation	74	74	–	105	105	–	7.1	7.1	–
Greece	71	3	68	85	4	81	3.3	5.5	3.2
Spain	49	34	15	59	26	33	3.5	-4.0	20.0
France	60	54	6	51	42	9	-2.5	-3.7	8.3
Italy	67	49	18	49	33	16	-4.4	-5.4	-1.8
Denmark	44	36	7	37	28	9	-2.6	-3.7	4.8
Poland	36	36	-	36	36	-	0.0	0.0	-
Germany	42	42	-	32	32	-	-3.2	-3.2	-

Source: FAO (2008a).

of total fed aquaculture production in Europe. The other countries in Europe that showed a sizeable contribution to total fed aquaculture tonnage in 2006 were the United Kingdom (10 percent), the Russian Federation (7 percent), Greece (6 percent) and Spain (4 percent).

Marine aquaculture of high-value species fed complete commercial diets is a predominant feature of European fed aquaculture. While registering a negative growth in freshwater sector, positive aquaculture growth rates in the marine sector during 2000–2006 were shown in Denmark, France and Spain (Table 3). Over the same period, Germany also registered negative growth in the freshwater sector (Table 3).

The overall trend in fed aquaculture in both the Asian and European regions is to focus on marine aquaculture (including brackishwater) of usually high-value species that require complete commercial or high performance diets.

1.2 PROJECTED GLOBAL AQUACULTURE PRODUCTION WITH CONTRIBUTIONS FROM ASIA AND EUROPE AND THE IMPLICATIONS FOR AQUAFEEDS

With stagnating global capture fisheries production, there is growing expectation for aquaculture to meet the shortfall of aquatic products and to cater to the growing demand of the increasing population. Predictions of the exact shortfall are imprecise: many forecasts have been developed based on a wide range of assumptions (Ye, 1999; Delgado *et al*., 2003; Wijkstrom, 2003; Dey, Rodriguez and Briones, 2004; Brugère and Ridler, 2004).

Delgado *et al*. (2003) with their International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT model) attempted to address the complexity inherent in creating a demand forecast by incorporating prices and their effects on consumer demand into the IMPACT model. Predictions were made using three main scenarios. Under the baseline scenario, which is the most plausible, "best guess" assumptions, global food-fish production was projected to reach 130 million tonnes by 2020 and aquaculture was expected to produce 41 percent (53.6 million tonnes) of this production. However, projected production at 2020 for all models (assuming a capture fisheries growth of 0.9 percent per year) has already been achieved (Table 4).

In their study for FAO, Brugère and Ridler (2004) adapted the studies of Delgado *et al*. (2003) for national predictions by considering government policy and production targets in national plans. Such national predictions were made for China, India, Indonesia, Thailand, Bangladesh, Chile, Viet Nam, the Philippines, Egypt, Brazil and Canada (Table 5).

The global actual average annual growth rate of 7.6 percent (from 2000 to 2006) (see footnote 2 in Table 4) and actual average annual growth rates of leading aquaculture producing countries in Asia (Table 5) suggest that all forecasted targets set for 2010 and 2020 by the forecast models in Table 4 are likely to be met.

TABLE 4
Forecast of global food-fish aquaculture production to total food-fish production

Forecast model	Forecast date/ per capita consumption (kg/year)	Food-fish demand by the forecasted date (million tonnes)	Food fish required from aquaculture to achieve the demand by forecasted date (million tonnes)		Actual aquaculture food-fish production in 2006 against production forecasts (%)[2]	
			Growing fisheries scenario	Stagnating fisheries scenario	Growing fisheries scenario	Stagnating fisheries scenario
IFPRI (Delgado *et al.*, 2003) Baseline	2020/17.1	130.0	53.6 (1.8%)[1]	68.6 (3.5%)[1]	96.4	75.4
Ecological[3] collapse	2020/14.2	108.0	41.2 (0.4%)[1]	46.6 (1.4%)[1]	125.5	110.9
Faster[4] aquaculture development	2020/19.0	145.0	69.5 (3.2%)[1]	83.6 (4.6%)[1]	74.4	61.8
Wijkstrom (2003)	2010/17.8	121.1	51.1 (3.4%)[1]	59.7 (5.3%)[1]	101.2	86.6
	2050/30.4	270.9	177.9 (3.2%)[1]	209.5 (3.6%)[1]	29.0	24.7
Ye (1999)	2030/15.6	126.5	45.5 (0.6%)[1]	65.1 (2.0%)[1]	113.6	79.4
	2030/22.5	183.0	102.0 (3.5%)[1]	121.6 (4.2%)[1]	50.7	42.5

[1] Forecasted average annual growth rate of aquaculture food-fish production to forecasted date.
[2] Actual global food-fish aquaculture production in 2006 was 51.7 million tonnes and the average annual growth rate from 2000 to 2006 was 7.6 percent.
[3] One percent annual growth trends in production, excluding supply response to price change, for all capture fisheries commodities including fishmeal and oil.
[4] Aquaculture output aggregate commodities are increased by 50 percent relative to the baseline scenario.
Source: Columns 2, 3 and 4 correspond to references in column 1. Column 5 is authors' computation.

TABLE 5
Growth rates of food-fish aquaculture in leading aquaculture producing countries in Asia

Country	Actual annual growth rates (%)			Forecasted growth rates (%)[1]	Forecast date[1]
	1980–1990[1]	1990–2000[1]	2000–2006		
China	17.1	33.8	6.7	3.7	2001–2010
Bangladesh	7.9	12.8	6.0	4.1	2001–2010
				3.5	2001–2020
India	11.4	6.8	10.1	8.2	2000–2005
				8.5	2001–2010
Indonesia	9.9	5.1	11.0	11.1	2003–2009
Philippines	6.3	0.3	9.7	13.4	2001–2004
Thailand	10.2	9.0	14.6	1.8	1996–2010
Viet Nam	11.8	8.5	38.8	10.0	2001–2010

[1] *Source*: Brugère and Ridler (2004).

These targets together with historic trends in species contribution to annual production can be used to forecast estimates of production tonnage and to predict trends in intensification of aquaculture practices for the various species groups farmed. These scenarios can help to understand the future demand and pressure on quantity and types of feed ingredients that may be required to meet production targets. For this purpose, the food-fish aquaculture production outlook projected to 2020 by Brugère and Ridley (2004) based on country national plans was used.

Contribution by species group to the forecasted aquaculture production (excluding aquatic plants) in 2020 is given in Table 6. To estimate the contribution of species groups to forecasted aquaculture production (excluding aquatic plants) to 2020 in countries listed in Table 6, the 17-year (1990–2006) average annual percentage contributions of the species groups (for Bangladesh, the 12-year average) were applied to 2020 production predictions.

Similarly, the contributions by species group were estimated for Europe based on the projected aquaculture production (excluding aquatic plants) forecasted by Failler (2008) in the 11 leading aquaculture producing countries in Europe (Table 7), which accounted for 88.0 percent of the total European aquaculture production (excluding aquatic plants) in 2006.

TABLE 6
Projected contributions by species group to aquaculture production (excluding aquatic plants) by 2020 in selected leading aquaculture countries in Asia

Country	Projected aquaculture production by 2020 (million tonnes)	Species groups[1]	Annual average % contribution to total aquaculture production 1990–2006[2]	Projected species group contribution to 2020 target (thousand tonnes)[3]
Bangladesh	1.34	Carps and other cyprinids	69.2	927.3
		Freshwater crustaceans	1.3	17.4
		Other freshwater fishes	21.1	282.7
		Marine shrimps and other crustaceans	8.5	114.0
China at 3.5% growth	52.22	Carps and other cyprinids	54.0	28 199.0
		Freshwater crustaceans	1.2	626.6
		Catfishes	1.5	783.0
		Other freshwater fishes	3.4	1 775.5
		Marine/brackishwater fishes	1.4	731.1
		Marine shrimps and other crustaceans	2.0	1 044.4
China at 2.0% growth	40.75	Tilapias and other cichlids	2.4	1 253.3
		Molluscs	34.2	17 859.2
		Carps and other cyprinids	54.0	22 005.0
		Freshwater crustaceans	1.2	489.0
		Catfishes	1.5	611.0
		Other freshwater fishes	3.4	1 385.5
		Marine/brackishwater fishes	1.4	570.5
		Marine shrimps and other crustaceans	2.0	815.0
		Tilapias and other cichlids	2.4	978.0
India	10.74	Molluscs	34.2	13 936.5
		Carps, barbs and other cyprinids	78.2	8 398.7
		Freshwater crustaceans	0.6	64.4
		Catfishes	5.6	601.4
		Other freshwater fishes	11.4	1 224.4
		Marine shrimps and other crustaceans	4.3	462.0
Indonesia	7.35	Carpsbarbs and other cyprinids	26.3	1 933.1
		Catfishes	6.5	477.8
		Other freshwater fishes	6.6	485.0
		Miscellaneous marine/brackishwater fishes	1.7	125.0
		Miscellaneous diadromous fishes	25.2	1 852.2
		Marine shrimps and other crustaceans	22.0	1 617.0
		Tilapia and other cichlids	11.7	860.0
Philippines	6.30	Carps, barbs and other cyprinids	2.0	126.0
		Catfishes	0.7	44.0
		Other freshwater fishes	0.2	12.6
		Marine/brackishwater fish	0.3	18.9
		Miscellaneous diadromous fishes	49.7	3 131.1
		Marine shrimps and other crustaceans	14.8	932.4
		Tilapias and other cichlids	24.8	1 562.4
		Molluscs	7.6	–
Thailand	0.84	Carps, barbs and other cyprinids	6.7	56.0
		Freshwater crustaceans	1.9	16.0
		Catfishes	16.1	135.0
		Other freshwater fishes	0.5	4.0
		Miscellaneous marine/brackishwater fishes	0.2	1.7
		Miscellaneous diadromous fishes	0.8	6.7
		Marine shrimps and other crustaceans	39.9	335.0
		Tilapias and other cichlids	11.4	96.0
		Molluscs	22.5	189.0
Viet Nam	5.20	Freshwater crustaceans	2.7	140.4
		Catfishes	20.3	1 056.0
		Other freshwater fishes	50.8	2 642.0
		Marine shrimps and other crustaceans	19.5	1 014.0
		Molluscs	6.7	348.4

[1] Species group based on FAO classification; [2] For Bangladesh 12-year average was considered to include all species groups. For other countries 17-year average was used to include all species groups; [3] Based on the long-term average species group contributions.

Source: Brugère and Ridley (2004).

TABLE 7
Projected contributions by species group to aquaculture production by 2020 in selected leading aquaculture countries in Europe

Country	Species groups	17-year average % contribution to total aquaculture production[1]	Projected aquaculture production by 2020 (tonnes)	Projected species group contribution to 2020 (thousand tonnes)[2]
Denmark	River eels	3.7	53 347	1 974
	Salmons, trouts, smelts	96.3		51 373
France	Carps and other cyprinids	3.2	307 497	9840
	Molluscs	77.8		239 233
	Flounders, halibuts, soles	0.2		615
	Marine/brackishwater fishes	1.3		3 998
	Miscellaneous freshwater fishes	0.4		1 230
	Salmons, trouts, smelts	17.0		5 227
Germany	Carps, barbs and other cyprinids	21.1	71 026	14 987
	Molluscs	29.0		20 598
	Miscellaneous freshwater fishes	9.2		6 534
	Salmons, trouts, smelts	40.6		28 837
Greece	Carps, barbs and other cyprinids	0.8	79 486	636
	Molluscs	31.8		25 277
	Marine/brackishwater fish	58.4		46 420
	Miscellaneous freshwater fishes	0.5		397
	River eels	0.8		636
	Salmons, trouts, smelts	7.6		6 041
Ireland	Molluscs	62.1	55 881	34 702
	Salmons, trouts, smelts	37.9		21 179
Italy	Carps, barbs and other cyprinids	0.3	279 363	838
	Molluscs	67.4		188 291
	Marine/brackishwater fishes	6.5		18 159
	Miscellaneous freshwater fishes	1.2		3 352
	River eels	1.5		4 190
	Salmons, trouts, smelts	22.7		63 415
	Sturgeons, paddlefishes	0.4		1 117
Netherlands	Molluscs	93.6	138 534	129 668
	Miscellaneous freshwater fishes	2.6		3 602
	River eels	3.6		4 987
	Salmons, trouts, smelts	0.2		277
Norway	Cods, hakes, haddocks	0.4	617 967	2 472
	Marine/brackishwater fishes	0.2		1 236
	Molluscs	0.3		1 854
	Salmons, trouts, smelts	99.1		612 405
Poland	Carps, barbs and other cyprinids	66.0	28 328	18 697
	Miscellaneous freshwater fishes	2.5		708
	Salmons, trouts, smelts	31.5		8 923
Spain	Carps, barbs, cyprinids	0.1	361 017	361
	Molluscs	84.1		303 615
	Flounders, halibuts, soles	1.1		3971
	Marine/ brackishwater fishes	3.4		12 275
	River eels	0.1		361
	Salmons, trouts, smelts	11.0		39 712
	Shrimps, prawns	0.1		361
	Tunas, bonitos, billfishes	0.2		722
United Kingdom	Molluscs	9.7	168 241	16 319
	Salmons, trouts, smelts	90.3		151 922

[1] For Norway, Poland and Germany, the 12-year average was considered to include all currently cultured species groups. For other countries, the 17-year average was used to include all species groups; [2] Based on the long-term average species group contribution.

Source: Failler (2008).

1.3 EMERGING TRENDS IN AQUACULTURE PRACTICES AND THE IMPLICATIONS FOR FEED DEMAND

1.3.1 Trends in the use of species groups in aquaculture practices

The detailed nature of aquaculture activities is hard to typify due to the great diversity of farming practices both among and within countries in Asia and Europe. At a glance, two species groups dominate aquaculture production in the two regions, carps in Asia and salmonids in Europe, and this will continue if current trends in growth continue. In addition to salmonids, marine (coastal) finfish make a significant contribution in terms of value in Europe. In Asia, carps, including barbels, and other cyprinids accounted for 62 and 55 percent of total Asian and world fed aquaculture production. In Europe, salmon and trout contributed 50 and 74 percent, respectively, to European total aquaculture, all fish farmed with commercial feeds.

This species group dominance in fed aquaculture in both regions and the recent focus on crustaceans, marine finfish, and other diadromous fishes point towards a tendency of increasing reliance on commercial aquafeeds for their production. Although carps are considered low-value species and are mainly fed farm-made aquafeeds (usually single ingredient feeds), their bulk production will place a heavy demand on feed ingredients, especially grains which will have to be procured on globally traded markets. Between 2000 and 2006, the production of marine shrimps and prawns, and freshwater crustaceans in Asia increased by 183 and 121 percent, respectively (Table 8), and in Europe, diadromous fish and coastal fish (including marine fish) production increased by 18 and 35 percent, respectively (Table 9), where feed demand is expected to be high.

It is worth noting that in the freshwater sector, the production of a number of carnivorous species has grown substantially since 2000. For example, production of pangas catfishes increased by 66.6 percent, amur catfish by 1 005 percent and snakeheads by 23 425 percent. Asian mariculture is generally dominated by high-value species such as penaeid shrimps and seabreams. Of the penaeid shrimps, whiteleg shrimp production has made significant advances in recent years to move into seventh place (Table 10). The production of other high-value species such as the oriental river prawn, giant tiger prawn, mandarin fish, Japanese amberjack and Japanese eel has also increased significantly. Thus, there is a notable move away from bulk production of low-value species and a focus on production of high-value species to meet growing demand of the local increasingly affluent populations and consequently greater pressure on sources of high-quality protein and oil. There are a number of high-value species worth highlighting as emerging species (Table 11). Since 2000, there was rapid growth in the production of high-value carnivorous species such as whiteleg shrimp, freshwater swamp eel, mandarin fish, channel catfish, red swamp craw fish, Chinese river crab and marine finfish.

TABLE 8
Production by main species group in Asia and its contribution to total fed aquaculture production

Species groups	Production (thousand tonnes)		Average annual percentage growth	% contribution to total Asian fed aquaculture production in 2006	% contribution to total world fed aquaculture production in 2006
	2000	2006			
Carps, barbs and other cyprinids	15 077	20 155 (34%)[1]	6	62 (33)[2]	55 (30)[2]
Miscellaneous freshwater fishes	2 358	4 420 (87%)	15	13 (7)	7 (12)
Marine shrimps and prawns	996	2 813 (183%)	30	9 (5)	8 (4)
Tilapias and other cichlids	993	1 836 (85%)	14	6 (3)	5 (3)
Freshwater crustaceans	475	1 048 (121%)	20	3 (2)	3 (2)
Miscellaneous coastal fishes	160	725 (353%)	59	2 (1)	2 (1)
Miscellaneous diadromous fishes	488	615 (26%)	4	2 (1)	2 (1)

[1] Percentage production increase; [2] Data in parenthesis includes plants.

Source: FAO (2008a).

TABLE 9
Production by main species group in Europe and its contribution to total and fed aquaculture production

Production groups	Production 2000 (tonnes)	Production 2006 (tonnes)	Average annual percentage growth	% contribution to total aquaculture production in Europe in 2006	% contribution to total fed aquaculture production in Europe in 2006
Salmons, trouts, smelts	926 459	1 091 505 (18%)[1]	3.0	50.0	74
Carps, barbs and other cyprinids	197 405	185 946 (-6%)	-1.0	9 .0	13
Brackishwater fishes	113 000	15 000 (35%)	5.0	6.0	9

[1] Percentage production increase.

Source: FAO (2008a).

TABLE 10
Production of top 20 fed-aquaculture species and species group in Asia (thousand tonnes)

Rank order of species and species group by production in 2006	2000	2006	Average annual growth 2000–2006 (%)	% contribution to the total world fed aquaculture production in 2006	Unit value 2006 (US$/tonne)
Silver carp	3 394	4 312	4.5	13.1	838
Grass carp	3 315	4 003	3.5	12.1	1 191
Common carp	2 461	2 978	3.5	9.0	864
Bighead carp	1 628	2 393	7.8	7.2	887
Crucian carp	1 379	2 097	8.7	6.3	727
Other freshwater fishes	1 881	2 040	1.4	6.2	1 404
Whiteleg shrimp	2	1 815	15 108	5.5	3 574
Nile tilapia	854	1 629	15.1	4.9	1 014
Rohu	734	1 332	13.6	4.0	1 173
Catla	602	1 331	20.2	4.0	994
Giant tiger prawn	623	648	0.7	2.0	4 738
White amur bream	512	594	2.7	1.8	837
Milkfish	468	585	4.2	1.8	1 104
Pangas catfishes	100	500	66.6	1.5	1 496
Chinese river crab	232	475	17.4	1.4	5 192
Mrigal	552	360	-5.8	1.1	844
Black carp	171	351	17.6	1.0	1 712
Other marine fishes	443	314	-4.8	0.9	1 045
Amur catfish	5	310	1 005	0.9	955
Snakehead	0.22	304	23 425	0.9	836

Source: FAO (2008a).

In Viet Nam, high-priced freshwater pangas catfish and marine crustaceans increased their combined contribution of 36.5 percent (pangas catfish – 21.8 percent, marine crustaceans – 14.7 percent) in 2000 to 49.5 percent (pangas catfish – 29.7 percent, giant tiger prawn – 9.9 percent, whiteleg shrimp – 9.9 percent) in 2006 to total fed aquaculture production, while of other freshwater fish the contribution decreased from 57.8 to 46.8 percent over the same period (Figure 3). Percentage contributions of the main species to aquaculture production in Thailand are presented in Figure 4. Of the main contributing species in Thailand, production of high-priced crustaceans and carnivorous catfish increased from 15.1 percent in 2000 to 65 percent of the total fed aquaculture production, while the contribution of other freshwater fish remained static at around 28 percent over the same period (Figure 4). The contribution of high-priced crustacean to total fed aquaculture production in Indonesia almost doubled from 11.5 percent in 2000 to 22.4 percent in 2006 (Figure 5). Thus, marine crustaceans and carnivorous catfish have been recent major cultured species throughout the subregion. Another species worth mentioning is the Nile tilapia, which increased its share from 5.2 percent in 2000 to 14.0 percent in 2006 in Indonesia, while in Thailand it maintained its contribution to total fed aquaculture production at between 14 and 15 percent over the same period.

TABLE 11
Changes in production trends of key traditional and emerging species in main Asian aquaculture producing countries

Country	Percentage average annual change in production from 2000 to 2006													
	Traditional species									Emerging species				
	Silver carp	Grass carp	Common carp	Bighead carp	Crucian carp	Other freshwater fish	Nile tilapia	Rohu	Catla	Whiteleg shrimp	Mandarin fish	Freshwater swamp eel	Catfish	Red swamp crawfish	Salmonids
Bangladesh	6.5 (120 816)					3.8 (133 495)		7.3 (120 446)	7.5 (104 435)						
China	2.5 (3 227 944)	4.2 (3 162 634)	3.7 (2 119 762)	7.8 (1 613 972)	8.7 (1 375 378)	-7.6 (1 377 534)	12.8 (629 182)			153.7[1] (100 000)	17.9 (98 859	8.9[4] (125 336)	45.8[4a] (45 552), 13.7[4b] (54 819), 12.0[4c] (177 406), 7.5[4d] (212 103)	25.5[9] (51 593)	45.0[1]
India	407.3 (14 215)							13.8 (516 542)	22.8 (497 200)						
Indonesia			6.2 (180 202)			0.03 (40 492)	56.8 (40 836)			27.7[2] (53 217)			24.0[5] (31 629)		
Iran	25.0 (17 000)	80.2 (2 000)	29.4 (7 000)	26.4 (1 500)											69.0
Myanmar			11.0[1] (30 000)			35.5[3] (73 854)		19.0 (93 948)					317.0[6] (500)		
Philippines							17.8 (76 036)								
Thailand							14.3 (82 363)			119.4[3] (60 000)			15.4[7] (76 000), 14.0[7a] (21 577)		
Viet Nam						27.8 (265 015)				233.3[3] (10 000)			58.3[8] (100 000		
Taiwan Province of China										58.0 (2 310)					

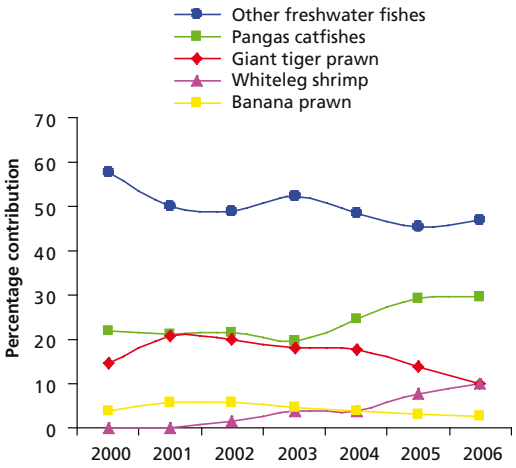
[1] % annual change in production (2001–2006); [2] % annual change in production (2004–2006), [3] % annual change in production (2002–2006); [4]% annual change in production (2003–2006), [4a]channel catfish % annual change in production (2003–2006), [4b] yellow catfish % annual change in production (2003–2006); [4c] snakehead % annual change in production (2003–2006); [4d] amur catfish % annual change in production (2003–2006); [5] torpedo–shaped catfish; [6] pangas catfish % annual change in production (2002–2006), [7] hybrid catfish; [7a]snakeskin gourami; [8] pangas catfish, [9] red swamp crawfish % annual change in production. (2003–2006).

Base year production figures (tonnes) are given in parenthesis.

Source: FAO (2008a).

FIGURE 3

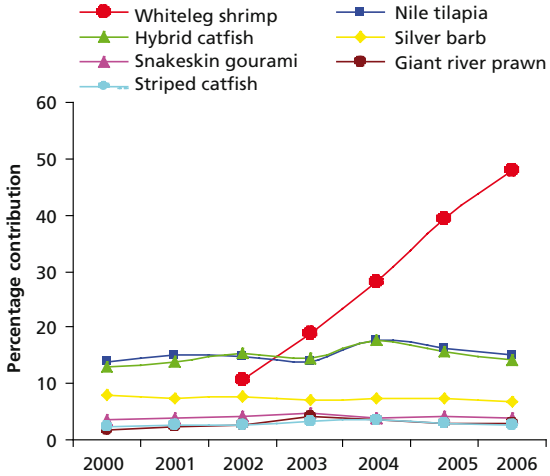
Percentage contribution of main species to aquaculture production in Viet Nam



Source: Adapted from FAO (2008a).

FIGURE 4

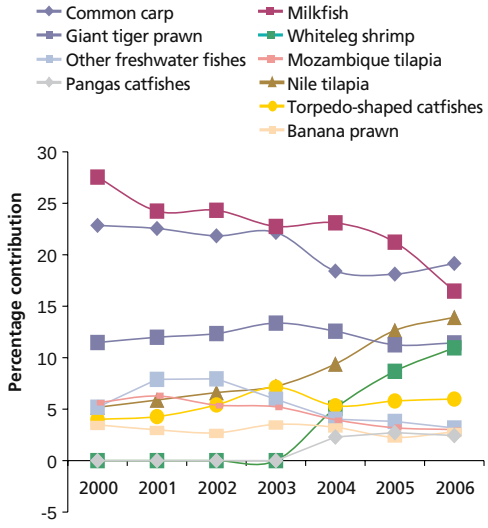
Percentage contribution of main species to aquaculture production in Thailand



Source: Adapted from FAO (2008a).

FIGURE 5

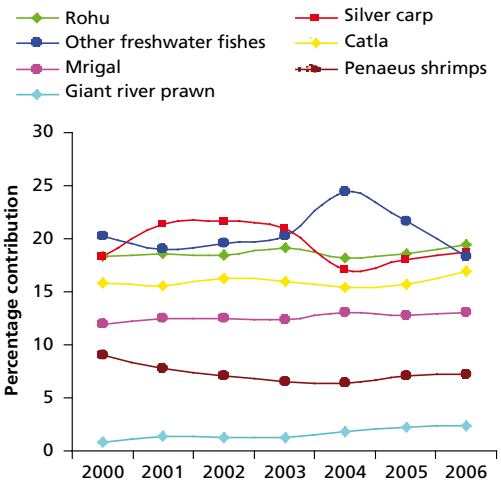
Percentage contribution of main species to aquaculture production in Indonesia



Source: Adapted from FAO (2008a).

FIGURE 6

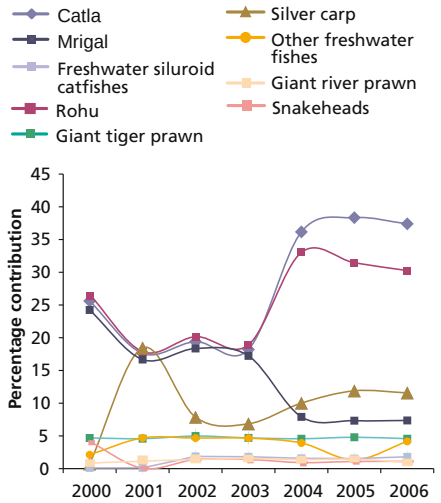
Percentage contribution of main species to aquaculture production in Bangladesh



Source: Adapted from FAO (2008a).

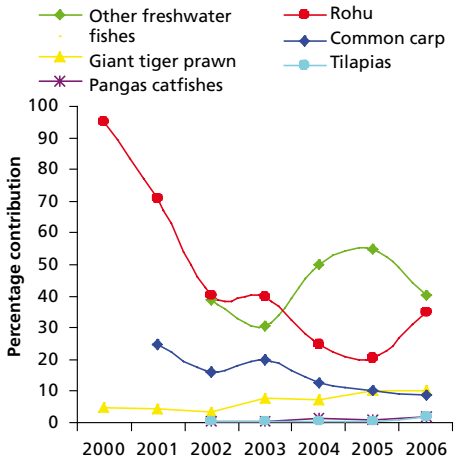
Indian carps (rohu, catla and mrigal) provide the mainstay of aquaculture production in Bangladesh and India. Bangladesh maintained a contribution between 46 and 49 percent (Figure 6) to the total fed aquaculture production over the period 2000–2006 while India's contribution over the same period was around 75 percent (Figure 7). Recent years have also witnessed a rapid increase in the production of silver carp (a 25–fold increase 2000-2006) in India. Crustacean contribution to total fed aquaculture production declined in the leading aquaculture producing countries in the subregion in recent years except in Myanmar. In contrast to Bangladesh (59 143 tonnes in 2000 to 64 700 tonnes in 2006) and India (90 975 tonnes in 2000 to 130 155 tonnes in 2006), rapid growth in high-priced crustacean production was seen in Myanmar which recorded a 12–fold increase in production from 2000 to 2006 (from 4 964 to 60 000 tonnes) and made a 5.0 to 10.4 percent contribution to total fed aquaculture production over the same period (Figure 8). Thus, the potential demand for performance diets in

FIGURE 7
Percentage contribution of main species to aquaculture production in India



Source: Adapted from FAO (2008a).

FIGURE 8
Percentage contribution of main species to aquaculture production in Myanmar



Source: Adapted from FAO (2008a).

future in the subregion is localized and may not be as high as in the Southeast Asian subregion. However, the trend in switching from extensive to semi-intensive carp culture will increase the demand for feed ingredients.

1.3.2 Trends in intensification of aquaculture practices

Aquafeeds usually account for 50–70 percent of production costs. Therefore, for most farming operations, the price of fish influences the expenditures for inputs such as feeds and feed ingredients. In general, low-value freshwater species are cultured in extensive or semi-intensive systems that need great volumes of water and land area, and inputs may be limited to fertilizers and single-ingredient farm-made aquafeeds. Accordingly, productivity is lower than that of higher value-species cultured in intensive systems using commercially formulated aquafeeds. Land and water resources, however, are already in short supply in many leading aquaculture producing countries in Asia due to land tenure structures, urbanization and industrialization, and competing demand for land and water for irrigation, compounded by increasing human population.

Current world aquaculture production, particularly low-value species, is heavily dependent on land-based production systems. In China, production in ponds accounted for 77 percent of the total inland aquaculture production (Ye, 1996). In the last decade, pond culture contributed 70–90 percent of total freshwater aquaculture production in Thailand (WorldFish Center, 2004a). FAO (2000) reported that about 78 percent of Indonesian farming households cultivate fish in small ponds of less than 500 m^2, and aquaculture is the main source of income for 66 percent of the households that cultivate fish in the paddies and ponds (WorldFish Center, 2004b). The most important farming system in Viet Nam is pond polyculture commonly stocked with Chinese carps (silver carp, grass carp and bighead) in the northern region and river catfish, common carp and Indian major carps (rohu, mrigal) in the southern region (WorldFish Center, 2004c). In recent years, red tilapia is cultured in ponds by using an intensive monoculture system. In addition, an integrated VAC system (V: garden, A: fish pond, C: livestock) is also common in Viet Nam. Thus, it can be estimated that overall 70–80 percent of freshwater aquaculture production in leading aquaculture producing countries comes from ponds and, therefore, land-based aquaculture will play an important role in future world aquaculture production. The availability of and continued access to land as well as fish prices, however, will dictate the pace of intensification.

To illustrate the challenges of meeting the projected aquaculture production in 2020 in two leading aquaculture producing countries, China and India, an increase in pond area would be on the order of 75 and 310 percent, respectively, in 2006 (Table 12).

Similarly, procurement of water, particularly freshwater, required to expand aquaculture would be a challenge due to competing demands for freshwater by other sectors (as shown in Table 13) and increasingly limited water availability for development.

Margat (1996) estimated that fisheries (including aquaculture) as an economic sector uses water without significant consumption and, hence, water is not lost from the hydrosphere. Although in hydrological terms water consumption in aquaculture is low, in physical and qualitative terms, aquaculture may make water unavailable for

TABLE 12
Additional pond area required to meet the 2020 aquaculture production target in leading aquaculture producing countries in Asia

Country	Production of low-value species in 2006 (tonnes)	Average freshwater fish production (tonne/ha/year)	Approximate pond area under culture (ha)	Forecasted production (tonnes) of low-value species in 2020	Approximate increase in required new pond area (ha)	Reference[1]
Bangladesh	642 554	2.8–3.0 (semi-intensive)	221 570	927 300	319 760 (44%)	Barman and Karim (2007)
China	16 641 016	7.5–15/1.5 to 2 years (semi-intensive); 15–22/ 2 years (intensive)	2 971 610	29 139 000	5 203 393 (75%)	Weimin and Mengqing (2007)
India	2 704 883	4–6; 10–15 (semi-intensive)	541 000	8 398 700	1 679 740 (310%)	Ayyappan and Ahamad Ali (2007)
Indonesia	451 936	2.82	160 261	2 793 100 2 578 100	914 422 (470%)	FAO (2000)
Philippines	168 136	3–4 (catfish); 1.3–7 (semi-intensive tilapia); 7–15 (intensive tilapia)	40 515	1 297 800	312 723 (672%)	Sumagaysay-Chavoso (2007)
Thailand	196 198	3–6 (tilapia and catfish) 9–50 (intensive tilapia)		128 000		Thongrod (2007)

[1] References cite average fish production and approximate pond area under culture; production figures in column 2 are from FAO (2008a); forecasted production figures in column 5 are authors' computations based on values from Table 6; figures in column 6 are authors' computations.

TABLE 13
Water consumption for irrigation and industrial and domestic uses in selected leading aquaculture producing countries in Asia

Country	Irrigation (million m³)		Industry (million m³)		Domestic (million m³)	
	1995	2025[1]	1995	2025[1]	1995	2025[1]
China	244 200 (85.0%)	230 900 (71.8%)	13 100 (4.6%)	31 100 (9.7%)	30 000 (10.4%)	59 400 (18.5%)
India	321 300 (91.9%)	331 700 (85.4%)	7 200 (2.1%)	15 700 (4.0%)	21 000 (6.0%)	40 900 (10.5%)
Indonesia	29 500 (73.7%)	30 300 (59.5%)	3 600 (9.0%)	7 100 (14.0%)	6 900 (17.2%)	13 500 (26.5%)
Philippines	15 900 (79.5%)	17 100 (62.4%)	2 800 (14.0%)	7 300 (26.6%)	1 300 (6.5%)	3 000 (10.9%)
Bangladesh	18 000 (87.8%)	19 200 (78.7%)	200 (1.0%)	500 (2.0%)	2 300 (11.2%)	4 700 (19.3%)
Thailand	24 100 (89.0%)	24 700 (78.4%)	1 100 (4.0%)	2 500 (8.0%)	1900 (7.0%)	4 300 (13.6%)
Japan	16 700 (56.4%)	14 800 (51.5%)	9 500 (32.1%)	10 300 (36.0%)	3 400 (11.5%)	3 600 (12.5%)
Viet Nam	10 200 (70.3%)	13 100 (69%)	2 500 (17.3%)	1 400 (7.4%)	1 800 (12.4%)	4 500 (23.6%)

[1] Forecast to 2025 is based on "business as usual" scenario; percentage of water consumption of total water use is given in parenthesis.

Source: Adapted from Rosegrant *et al.* (2002).

other uses. Therefore, we anticipate that aquaculture will compete with other economic users of freshwater as pressure on the national renewable water resources increases.

As a rough estimate, if the critical ratio of water withdrawal exceeds a quarter of actual renewable water resources of a country, water can be considered a limiting factor to development and, reciprocally, the pressure on water resources can have a direct impact on all sectors, from agriculture to environment and fisheries (FAO, 1997). Moreover, a high dependency ratio, meaning the proportion of water in a country that is received from external sources (see Box 1), indicates the vulnerability of a country to the effects of extraction, impoundment and pollution. A high dependency ratio will inevitably have important implications for water-sharing policies, cooperation and conflicts, while a low dependency ratio for a water-scarce nation means it has to make careful decisions on improving future internal efficiencies in water usage. The high percentage of the water withdrawal indicator (critical ratio) among the leading

BOX 1

Schematic representation of renewable water resources

Internal renewable water resources (IRWR) are generated from the endogenous precipitation (precipitation within the country) (Figure a).

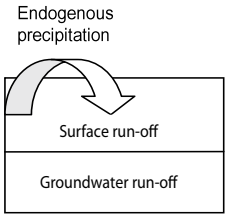


Figure a

The external renewable water resources (ERWR) are the water that enters from the upstream countries through rivers and aquifers (shared lakes, border rivers, transboundary flow) (Figure b).

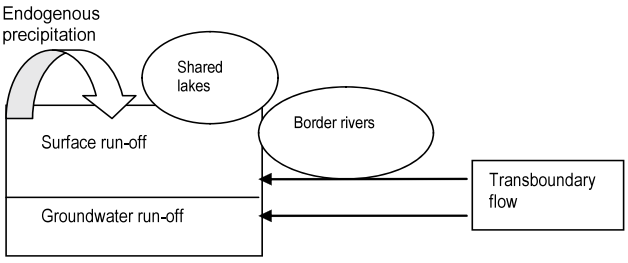


Figure b

The actual renewable water resources (ARWR) of a country is defined as the sum of IRWR and ERWR, taking into consideration the quantity of flow reserved to upstream and downstream countries through formal or informal agreements and treaties and possible reduction of external flow due to upstream water abstraction (Figure c).

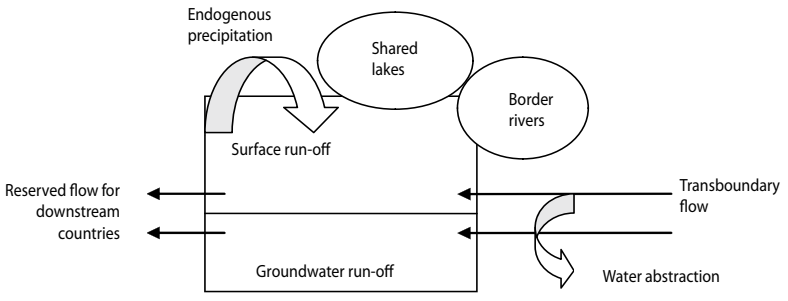


Figure c

TABLE 14
Some possible indicators for sustainable water resources development in leading aquaculture producing countries in Asia

Country	Some possible indicators for sustainable water resources development			
	Internal renewable water resources (IRWR) (million m^3)	Actual renewable water resources (ARWR) (million m^3)	% water withdrawal from ARWR	Dependency ratio
China	2 812 000	2 829 600	22.3	0.6
India	1261000	1 896 700	34.0	33.5
Indonesia	2 838 000	2 838 000	3.0	00
Philippines	479 000	479 000	6.0	00
Bangladesh	105 000	1 210 600	6.5	91.3
Thailand	210 000	409 900	21.2	48.8
Japan	430 000	430 000	20.6	00
Taiwan Province of China	67 000	67 000	-	00
Viet Nam	366 500	891 200	8.0	58.9

Source: Adapted from WRI (2008).

aquaculture countries in Asia, points to a possible water limiting factor for aquaculture development in China, India, Thailand and Japan and the high dependency ratio indicator for Bangladesh and Viet Nam may suggest increased competition from other sectors and countries with which they share this resource (Table 14).

In the light of probable increased competition for land and water throughout many aquaculture producing countries in Asia, there will inevitably be increasing pressure to improve productivity through intensification. This trend is already evident. The production of low-value (in marketing term) herbivore and omnivore species is changing rapidly from extensive to semi-intensive systems using low-cost farm-made aquafeeds. This is illustrated by the recent trend in global aquafeed production and number of farms dependent on aquafeeds. In 2003, global aquafeed production was estimated at approximately 19.5 million tonnes, but it is anticipated that it would increase to over 37.0 million tonnes by the end of this decade (Barlow, 2000). According to an estimate based on the aquafeed production of the seven leading aquaculture producing countries (Bangladesh, China, India, Indonesia, the Philippines, Thailand and Viet Nam), this trend was also evident from the increase in the use of industrial aquafeeds from 10.3 million tonnes in 2003 to an estimated 22.2 million tonnes in 2013 in Asia alone (De Silva and Hasan, 2007).

It is also predicted that the usage of farm-made aquafeeds may go up over the next ten years, to 30.7 million tonnes in 2013 from 19.3 million tonnes, representing a growth of 60 percent from the 2003 level (De Silva and Hasan, 2007). In a recent analysis based on case studies in six leading Asian aquaculture producing countries, 50–70 percent of farms, with the exception of China, were dependent on farm-made aquafeeds. China's dependency was only 25 percent. The number of semi-intensive farms depending on complete commercial feeds is highest in India (74 percent) followed by China (46 percent) (Rola and Hasan, 2007). China and India together accounted for 90 percent of the world's carp and other cyprinid production, and 92 percent of Asia's carp and other cyprinid production, indicating a trend towards the mainstay of low-value species but semi-intensive farming using commercial complete feeds as opposed to feeds made on-farm. These developments suggest a trend towards increasing intensification of production and consequently increasing dependency on formulated complete diets.

1.4 FISH CONSUMPTION PATTERNS IN ASIA AND EUROPE AND THE IMPLICATIONS FOR THE USE OF FEED IN AQUACULTURE

During the 1990s, global apparent consumption of fish increased. The global average apparent per capita consumption increased from about 9 kg per year in the early 1960s to 16.3 kg in 1999 (WHO, 2002). The global per capita availability of fish and fishery products has, therefore, nearly doubled in 40 years, outpacing population growth. This

TABLE 15
Per capita fish consumption (kg/person/year) in Asia and Europe

Country	1985	1990	1995	2000	2003	Average growth (%)
Bangladesh	7.0 (6.0)	7.0 (6.0)	8.0 (7.0)	11.0 (10.0)	11.0 (9.0)	57 (83)
China	7.0 (2.0)	11.0 (4.0)	20.0 (7.0)	25.0 (10.0)	25.0 (10.0)	257 (400)
India	3.0 (1.0)	3.0 (1.0)	4.0 (2.0)	4.0 (2.0)	4.0 (2.0)	33 (100)
Indonesia	13.0 (3.0)	14.0 (3.0)	17.0 (4.0)	20.0 (4.0)	20.0 (4.0)	54 (33)
Japan	69.0 (4.0)	71.0 (5.0)	71.0 (5.0)	67.0 (5.0)	66.0 (5.0)	-4 (25)
Myanmar	14.0 (1.0)	15.0 (1.0)	14.0 (2.0)	18.0 (2.0)	18.0 (3.0)	29 (200)
Philippines	33.0 (5.0)	36.0 (5.0)	32.0 (4.0)	29.0 (4.0)	28.0 (5.0)	-15 (0)
Thailand	20.0 (3.0)	20.0 (4.0)	33.0 (6.0)	30.0 (7.0)	30.0 (7.0)	50 (133)
Viet Nam	12.0 (3.0)	13.0 (3.0)	16.0 (5.0)	19.0 (7.0)	17.0 (6.0)	42 (100)
Asia	10.0 (2.0)	12.0 (3.0)	16.0 (4.0)	17.0 (6.0)	17.0 (6.0)	70 (200)
South Asia	3.0 (1.0)	4.0 (2.0)	4.0 (2.0)	5.0 (3.0)	5.0 (3.0)	67 (200)
East and Southeast Asia	21.0 (3.0)	22.0 (3.0)	24.0 (4.0)	25.0 (4.0)	25.0 (5.0)	19 (67)
Europe	18.0 (1.0)	20.0 (1.0)	19.0 (2.0)	19.0 (2.0)	20.0 (2.0)	11 (100)
Western Europe	21.0 (1.0)	24.0 (1.0)	25.0 (2.0)	25.0 (2.0)	26.0 (2.0)	24 (100)
Eastern Europe	8.0 (1.0)	6.0 (1.0)	6.0 (1.0)	7.0 (1.0)	8.0 (1.0)	0 (0)
World	12.0 (2.0)	13.0 (2.0)	15.0 (3.0)	16.0 (4.0)	16.0 (4.0)	33 (100)

The number in parenthesis within the table denote freshwater fish consumption.

Source: Adapted from Laurenti (2007).

development was heavily dominated by events in China, which emerged as the world's largest fish producer during this period (Popkin, 2001). In fact, excluding China, the apparent consumption per person in the rest of the world actually declined from 14.4 kg in 1990 to 13.1 kg in 1999. However, it is important to note that such global figures mask the very wide differences among countries in the amount of fish used for food consumption (FAO, 2003) (Table 15).

In both Asia and Europe, the low proportion of freshwater fish in per capita fish consumption indicates the preference for marine (including brackishwater) fish. East and Southeast Asia, where aquaculture is growing fast, this trend is quite evident when fish consumption is compared with South Asia. A majority of the cultured marine species are high-value and depend on high-quality complete diets.

Driving forces that influence consumer behaviour and lead to an increase in the demand for various types of fish and meat are urbanization, lifestyle and dietary habits (Popkin, 1999). The forces that influence fish consumption, however, may vary between developing and developed countries. Delgado (1999) pointed out that in developing countries, increasing income and urbanization would be the leading factors for the increasing demand for fish and meat by 2020 (Delgado *et al*., 2003). Lubchenco (2003) claimed that the increasing demand in developed countries is driven by increased consumer awareness of the health and nutritional benefits of seafood, increased standardization and availability of products and cheaper prices. The relationships between income and urbanization and fish consumption are clearly important factors to be taken into consideration in the calculation of future fish demand and type of fish as there is a trend in urbanization globally.

The increase in population between 2005 and 2030 is expected to be 1.7 billion. This increase will be primarily accounted for by the growth in the urban areas of less developed regions, which is expected to reach 3.9 billion from 2.3 billion in 2005 (UN, 2007). Unlike developing regions, developed regions had already attained high levels of urbanization by 1950 (Table 16). It is projected that similar levels of urbanization will take place in the developing world. Between 2000 and 2030, Asia's urban population will increase from 1.36 billion to 2.64 billion, that of Africa from 294 million to 742 million, and that of Latin America and the Caribbean from 394 million to 609 million. As a result of these shifts, developing countries will have 80 percent of the world's urban population in 2030 (UN, 2007). By then, Africa and Asia will host almost

TABLE 16
Proportions of urban and rural populations in the regions of the world

Area/region	Percentage urban			Percentage rural		
	1950	2000	2030	1950	2000	2030
Africa						
Eastern Africa	5.3	20.7	33.7	94.7	79.3	66.3
Central Africa	13.9	37.4	54.9	86.1	62.6	45.1
Northern Africa	24.8	48.9	64.1	75.2	51.1	35.9
Southern Africa	37.6	53.9	68.6	62.4	46.1	31.4
Western Africa	10.4	39.3	57.4	89.6	60.7	42.6
Asia						
Eastern Asia	16.5	40.4	62.5	83.5	59.6	37.5
South-central Asia	16.5	29.4	42.9	83.5	70.6	57.1
Southeast Asia	15.4	39.6	61.2	84.6	60.4	38.8
Western Asia	28.6	63.6	72.1	71.4	36.4	27.9
Europe						
Eastern Europe	39.2	68.3	73.7	60.8	31.7	26.3
Northern Europe	69.0	83.4	87.4	31.0	16.6	12.6
Southern Europe	45.1	65.4	74.3	54.9	34.6	25.7
Western Europe	62.3	76.2	82.6	37.7	23.8	17.4
Latin America & Caribbean						
Caribbean	36.0	62.1	72.6	64.0	37.9	27.4
Central America	39.3	68.8	77.6	60.7	31.2	22.4
South America	43.8	79.4	88.1	46.2	20.6	21.9
North America	63.9	79.1	86.7	36.4	20.9	23.3
Oceania						
Australia/New Zealand	76.2	86.9	91.5	23.8	13.1	8.5
Melanesia	5.4	19.2	27.6	94.6	81.8	72.4
Micronesia	31.6	65.7	76.6	68.4	34.3	23.4
Polynesia	23.7	41.1	53.2	76.3	58.9	56.8

Source: UN (2007).

seven out of every ten urban inhabitants in the world. With urbanization, people are increasingly drawn towards urban settlements and as both the level and distribution of income changes, the pattern of fish demand will change, with important implications for the demand for fish, and, in turn, implications for the type of feed used.

As Huang, Rozelle and Rosegrant (1997) suggest, increased urbanization may account for an increased demand for fish of 10 percent in China. Consumers are as diverse in their consumption preferences as the fish products they consume. The increasing demand in developed countries, where urbanization is high, has been mostly for high-value fish species. Thus, the demand for high-value species, which consume high-quality feeds, may increase in developing countries as urbanization increases. Although growth in all aquaculture sectors is increasing (see Section 1.2), it can already be seen that exceptionally high growth rates have occurred in the production of high-value and carnivorous species such as freshwater swamp eel, mandarin fish, channel catfish, red swamp crawfish and freshwater swamp eel.

The increasing supply of high-value species is associated with decreasing market price of high-value species. The decrease in market price of high-value species may be attributed to the promotion of intensive practices in recent years to increase production, development of complete commercial performance diets and the competitive market environment. For example, the rapidly increasing production of whiteleg shrimp has led to price depression in the international markets (FAO, 2006). Similarly, farm-gate value for 15–20 g size whiteleg shrimp has steadily decreased from US$5/kg in 2000 to about US$3.00–3.50/kg in 2005. The market prices of European seabass and gilthead seabream imported to Italy from Greece dropped from €7/kg in 1999 to €4.6/kg in 2007 and €6/kg in 1999 to €3.8/kg in 2007, respectively (Fish Site, 2007).