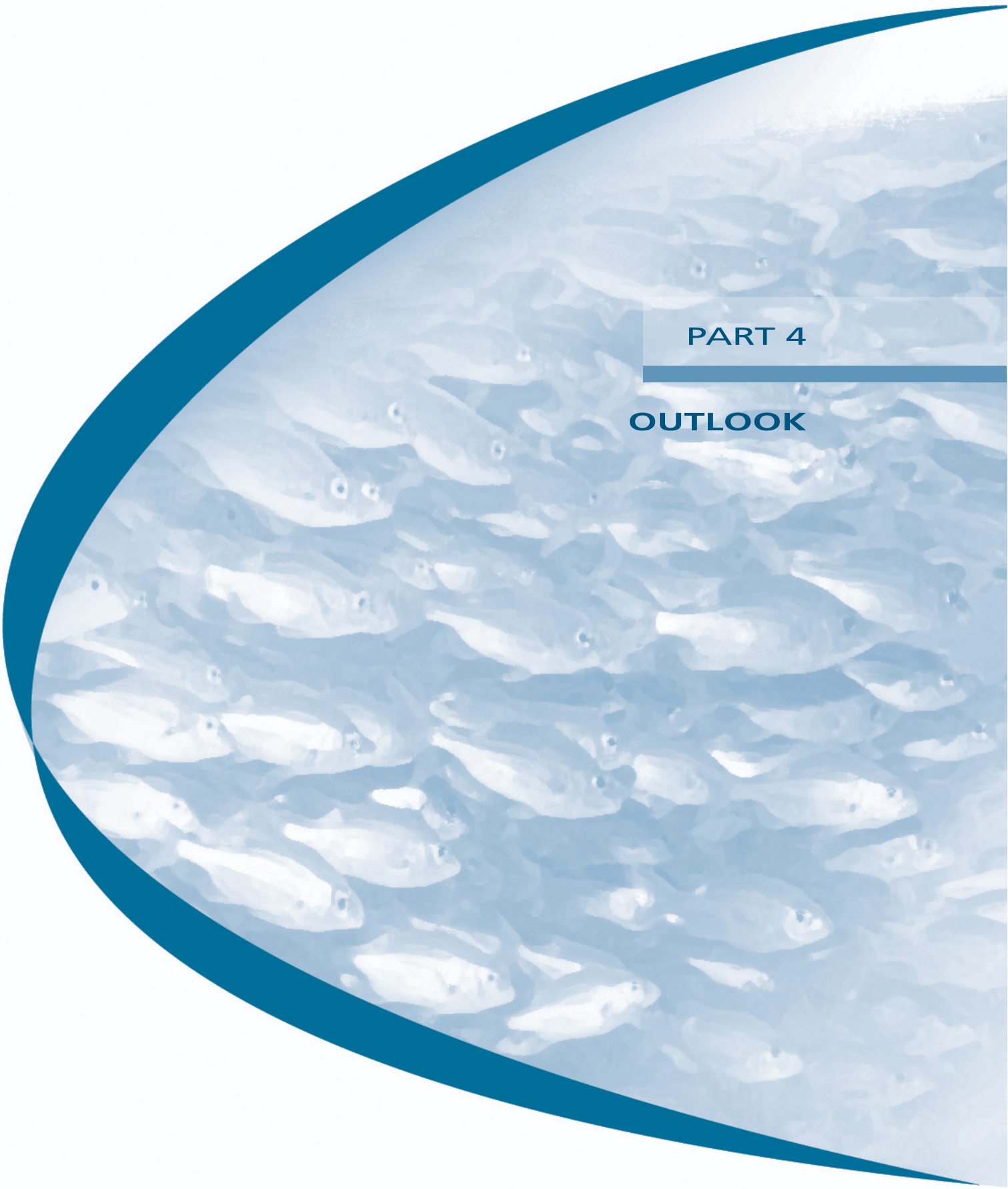

PART 4

OUTLOOK

OUTLOOK

Constraints on growth in the aquaculture sector

HAVE PER CAPITA SUPPLIES OF FISH FOR HUMAN CONSUMPTION PEAKED?

Will land and water suffice for agriculture to feed a growing human population? The question about humankind's ability to feed itself is old and recurring. However, only fairly recently has fish been included in this concern. As late as the first half of the twentieth century, the sea was considered a virtually inexhaustible reservoir of fish for people to exploit. It was only in mid-century that marine biologists started to gain an audience when they affirmed that wild fish stocks were finite and could be fished too heavily. These concerns became serious early in the second half of the century, when the capacity to overfish wild stocks became apparent. However, aquaculture started to grow at about that time and, for many, this was reassuring. It sustained the hope that there would be enough fish to eat also in the future.

In the last three decades, aquaculture has grown rapidly. In the 1970s, it accounted for about 6 percent of fish[1] available for human consumption; in 2006, the figure was 47 percent.

However, overall the rate of growth in aquaculture (measured in production volume) has started to slow. For the world as a whole, while the average yearly growth rate had been 11.8 percent in the period 1985–94, it was 7.1 percent in the following decade.

This slowdown is also reflected in the quantities of fish and fish products made available for human consumption (Table 15). Per capita availability, which grew, albeit slowly, in the 1990s and early years of the following decade, seems to be levelling off.[2] The question is whether per capita supplies of fish for human consumption will remain steady or peak in the near future and then start to fall.

The world's supply of fish available for human consumption is determined by capture fisheries production (marine and freshwater) and aquaculture production, less the share of this total withdrawn from human consumption and used for other purposes. Given the strong likelihood that fish landings will remain stagnant in capture fisheries, aquaculture remains the only apparent means to expand world supplies. So, what does the future look like for aquaculture?

In the late twentieth century, when capture fishery production levelled off and aquaculture production increased rapidly, most observers tended to conclude that any supply shortfall would be filled by aquaculture production. This opinion is still widely held (Box 13).

More serious attempts to predict future fish supplies have tended to predict capture fisheries production independently (by considering the state of stocks and fishing effort in capture fisheries) and then deduct projected landings from demand (arrived at by considering population growth and income elasticities of demand for fish) in order to arrive at the quantity that aquaculture would have to produce. There have been few attempts to predict future aquaculture production by examining the prospects for culture of various species, culture systems and economic conditions.

However, the popular assumption – that aquaculture production will grow as long as demand does, and do so in volumes that will virtually match demand growth – is unfortunate as it sends a surreptitious message that there is a considerable degree of automatism in the expected aquaculture response and, thus, little need for enabling public polices. Such a view of the seafood sector is misleading for those who formulate public policies towards aquaculture and capture fisheries. Aquaculture-enabling policies are essential for the steady and sustainable growth of the sector.

Table 15
Per capita supply of fish by groups of countries

Selected groups and countries	Per capita supply of fish (live weight equivalent)			Annual change	
	1985	1995	2005	1985–1995	1995–2005
	(Kilograms)			(Percentage)	
Africa	7.5	7.1	8.3	–0.6	1.5
Sub-Saharan Africa	7.8	7.0	7.6	–1.0	0.8
North Africa	6.4	7.6	11.9	1.8	4.6
Latin America and the Caribbean	8.3	9.1	8.7	0.9	–0.4
Latin America	7.9	9.0	8.7	1.3	–0.3
Caribbean	12.6	10.5	9.6	–1.8	–0.9
Near East	4.8	5.8	6.2	1.9	0.7
Asia and the Pacific	11.4	16.7	18.9	3.9	1.2
South Asia	3.7	4.6	5.5	2.1	1.8
East and Southeast Asia	15.8	24.4	28.0	4.4	1.4
China	6.7	20.3	26.1	11.8	2.5
Japan	69.7	71.1	61.2	0.2	–1.5
Other East and Southeast Asia	22.2	22.8	25.7	0.3	1.2
Oceania	19.7	19.9	24.5	0.1	2.1
Australia and New Zealand	17.3	19.9	24.9	1.4	2.3
Other Oceania	27.2	19.8	23.4	–3.1	1.6
Europe (+ Cyprus and Israel)	18.3	18.5	20.8	0.1	1.2
EU(27)	18.9	20.9	22.5	1.0	0.7
Non-EU countries	10.9	14.2	17.4	2.7	2.0
North America	19.0	21.9	24.1	1.4	1.0
United States of America	18.8	21.8	23.4	1.4	1.0
Canada	19.7	22.7	24.1	1.4	0.6
Other countries in North America	63.4	59.5	61.1	–0.6	0.3
World	12.6	14.9	16.4	1.7	1.0
Low-income food-deficit countries	6.8	11.6	13.8	5.5	1.8

Source: FAO Fisheries and Aquaculture Department.

Worldwide, the rate of growth in aquaculture production is slowing. Surveys of fish farmers and other aquaculturists show that, generally, the reasons for this are that those who want to expand production face various constraints and obstacles.[3] They would probably be better equipped to overcome them, and increase production, if the price levels for fish rose. However, it would seem unwise to rely only on an increase in price, which, if it happens, is likely to be in nominal rather than real terms.

The rest of this "Outlook" reports on the perceived obstacles to aquaculture growth. The purpose is to try to identify which of the various potential constraints are likely to become effective constraints in the near future. Such information should interest public administrations that use public resources to promote continued aquaculture growth.

Box 13

Will aquaculture ensure increased fish supplies?

"The aquaculture sector in developing and developed countries has witnessed spectacular production increases over the past two decades; and there is nothing to suggest that this will change." (Organisation for Economic Co-operation and Development. 2007. *Globalisation and fisheries. Proceedings of an OECD–FAO workshop.* Paris.)

"As seafood demand continues to grow, increasing demand is being satisfied from aquaculture sources in both developed and developing countries." (Ibid.)

"… aquaculture currently accounts for 43 percent of global fish production used for human consumption and is expected to grow and compensate for the predicted global shortage of supply from capture fisheries and the demands of society." (Ibid.)

"Aquaculture production has continually outstripped projections, and there is little reason to believe that it will not continue to do so." (World Bank. 2006. *Aquaculture: changing the face of the waters*. World Bank Report No. 36622-GLB. Washington, DC.)

RECENT GROWTH IN AQUACULTURE PRODUCTION

A closer look at the recent history of aquaculture growth shows that growth has not been uniform. It has been faster in some regions of the world than in others (Table 16). The same pattern appears when production is broken down by species (Table 17). For some species (trout and carp in Europe), growth has virtually stopped. For others (tilapia and catfish), growth appears high and steady, while some species either have not yet taken off (cod) or seem about to take off (cobia).

The simple explanation for these differences is that producers (aquaculturists and others who earn a living processing, transporting and selling fish) have different abilities to provide fish at prices consumers can afford. In addition, some aquatic species are easier to handle in captivity than others. The very rapid growth in production of cultured whiteleg shrimp (*P. vannamei*) in the past ten years can be attributed to the ease of obtaining seed in hatcheries from cultured broodstock, and to the fact that it is disease-free.

However, the underlying reasons for these differences are many, and several are not specific to aquaculture.

In developed economies, stagnation in production in established sectors, such as aquaculture, is usually a sign of a well-developed farming technology and a well-established market. On the one hand, consumers are aware of the product and will not consume more unless the price falls or competing products become more expensive. On the other, established producers have difficulties in modifying their methods to reduce production costs permanently. They have tailored management to their own conditions, and input and output prices have settled. Neither the individual producer nor the individual consumer can modify them. In such situations, profit margins are usually small, and new entrepreneurs are reluctant to enter the industry. In these mature industries, expansion constraints are real and effective. They can be interpreted as an indication that, for society as a whole, it is not optimal to dedicate more resources to aquaculture.

In China, on the other hand, aquaculture grew slowly prior to 1980, which could be interpreted as a sign of a mature industry – as aquaculture had been practised in China for centuries. However, aquaculture then started to expand rapidly, and

Table 16
Average yearly growth in aquaculture production by groups of countries

Selected groups and countries	Production			Annual change	
	1985	1995	2005	1985–1995	1995–2005
		(Million tonnes)		(Percentage)	
Africa[1]	0.05	0.11	0.65	7.5	19.4
Sub-Saharan Africa	0.01	0.03	0.10	12.1	11.4
North Africa	0.04	0.08	0.55	5.9	21.9
Latin America and the Caribbean	0.08	0.44	1.40	19.3	12.3
Latin America	0.07	0.41	1.37	19.4	12.8
Caribbean	0.01	0.03	0.03	17.2	0.5
Near East	0.03	0.06	0.28	8.2	16.1
Asia and the Pacific	6.21	21.69	43.34	13.3	7.2
South Asia	0.77	2.00	3.95	10.1	7.0
East and Southeast Asia	5.42	19.59	39.24	13.7	7.2
China	3.15	15.86	32.42	17.5	7.4
Japan	0.66	0.82	0.75	2.2	–0.9
Other East and Southeast Asia	1.61	2.92	6.08	6.1	7.6
Oceania	0.02	0.09	0.15	15.9	4.7
Australia and New Zealand	0.02	0.09	0.15	15.8	4.7
Other Oceania	0.00	0.00	0.00	20.0	6.5
Europe (+ Cyprus and Israel)	1.03	1.60	2.17	4.5	3.1
EU(27)	0.97	1.18	1.28	2.0	0.8
Non-EU countries	0.06	0.42	0.90	21.1	7.9
North America	0.33	0.48	0.65	3.7	3.1
United States of America	0.32	0.41	0.49	2.5	1.8
Canada	0.01	0.07	0.15	22.2	9.0
Other countries in North America	–	–	–	–	–
Others (= USSR until 1991 + others NEI)	0.29	–	–	–	–
World	8.02	24.38	48.49	11.8	7.1
Low-income food-deficit countries	4.66	19.21	39.09	15.2	7.4

Note: NEI = not elsewhere included.
[1] Egypt, Libyan Arab Jamahiriya and Sudan are also included in Near East.
Source: FAO Fisheries and Aquaculture Department.

did so at very high rates in the 1990s and into this century. The main cause was the modification of macroeconomic policies – *inter alia* in the form of weakened price controls for the aquaculture sector – that increased economic growth generally and enabled fish farmers to respond quickly and effectively to an opportunity to augment incomes by expanding production as possibilities appeared. Again, it was mainly factors exogenous to aquaculture that removed constraints and obstacles to aquaculture production. It was not the fish farmers themselves – they simply responded to an opportunity.

Table 17
Average yearly growth rates in aquaculture production by decade by groups of species

	Production			Annual change	
	1985	1995	2005	1985–1995	1995–2005
		(Million tonnes)		*(Percentage)*	
Freshwater fishes	4.35	12.94	26.05	11.5	7.2
Diadromous fishes	0.67	1.52	2.88	8.5	6.6
Marine fishes	0.22	0.53	1.65	9.0	11.9
Crustaceans	0.26	1.10	4.00	15.6	13.8
Molluscs	2.49	8.23	13.47	12.7	5.1
Aquatic animals NEI	0.03	0.06	0.44	7.1	22.9

Note: NEI = not elsewhere included.

Where aquaculture is new, growth can be rapid, particularly in developed economies. This is particularly the case in the wake of technological or management breakthroughs in the developed economies of Europe and North America, and for species that are expensive, "up-market" and well known. Modern, readily accessible means of communication and transportation make it possible to offer the product to a large market. Where the initial earnings are high, entrepreneurs are drawn into the sector, and production expands rapidly. Most mature aquaculture industries (e.g. salmon and trout worldwide; eel in Japan; oysters, seabass and seabream in Europe; milkfish in the Philippines; and catfish in the United States of America) experienced initial phases of very rapid growth.

When aquaculture becomes established in poor regions of developing countries, it is not likely to expand at a pace that is much different from that of the economy as a whole. Often, this is because poor infrastructure (especially rudimentary communication facilities and deficient transport systems) imposes large costs on any products intended for sale outside the vicinity of the fish farm. Thus, resource-poor fish farmers face constraints they can do little to circumvent. However, access to foreign capital and markets can change the situation dramatically, as has been the case in Honduras (where foreign interests have helped to develop tilapia culture for the market of the United States of America).

The growth rates for aquaculture in Africa (see Table 16) seem to contradict the above. There are several reasons for the high growth rates in Africa:

- the starting point is low absolute amounts of aquaculture production, meaning that increases that are small in absolute terms become large in relative terms;
- the inflow of foreign capital and expertise in aquaculture ventures that supply overseas markets;
- growing public support for aquaculture in regions with above-average economic growth.

Thus, the actions that have facilitated development – in a sense, removed obstacles – have come from outside the aquaculture sector. It is not the fish farmers who have created the circumstances that have made aquaculture possible.

It seems clear that aquaculture entrepreneurs have not been solely responsible for the growth of the industry and that this is likely to continue to be the case. Therefore, if governments want to ensure continued growth in aquaculture and its sustainability, they have a strong interest in actively helping the industry to remove constraints.

However, the constraints are many, and they are unlikely to all be simultaneously effective, or to be amenable to modification by all. It would seem desirable to:
(i) have an idea of which of the current constraints are likely to be effective

constraints in the coming decade; and (ii) know who should do what to alleviate them. The situation will differ by geographical region and by type of aquaculture. To a large extent, the importance of these constraints, and the associated urgency to remove them, will be decided by the expected evolution of the market for fish and fish products.

Since agriculture began, farmers have been overcoming the obstacles that nature has raised against them. However, the time when farmers removed all obstacles on their own is long gone. This is also true for aquaculture, not only for the modern aquaculture entrepreneur but also for the small-scale, commercial fish farmer in developing economies. In modern aquaculture, development is now a joint effort among farmers, investment concerns, equipment manufacturers, service suppliers, scientists and government.

CONSTRAINTS ON AQUACULTURE

Types of constraints

Constraints on aquaculture can take many forms. Active or potential fish farmers may be hindered by a lack of: (i) knowledge about how to go about the business of fish farming; (ii) access to the necessary capital or fixed assets; and (iii) access to the necessary inputs (seed, feed, fertilizer, etc.). They may also be prevented by the public administration (or in extreme cases by civil society) from engaging in an activity that seems perfectly viable from the economic point of view but is considered harmful to other interests.

Entrepreneurs, small or large, are not the only group of individuals concerned about aquaculture and its development. Scientists, administrators and policy-makers are also interested. Moreover, although a step or two removed from entrepreneurial activities, they do discuss the obstacles that in one way or another confront entrepreneurs, that is those who must suffer the consequences of such obstacles.

Entrepreneurs face constraints when they want to: (i) initiate aquaculture operations; (ii) expand an already functioning aquaculture enterprise; or (iii) streamline operations in order to reduce costs and expand market share.

As it is the farmers' perspective and needs that in the end determine what is and what is not a true constraint, it may be useful to divide constraints into categories:

- microeconomic constraints (or access to capital assets, recurrent inputs and markets);
- knowledge constraints (management and technical expertise);
- social constraints (public policies and externalities).

Neutralizing constraints

Microeconomic constraints

Worldwide, most aquaculture entrepreneurs (small or large) decide whether to start or close their farm, where to buy inputs and who to sell their products to. They are economic agents in what is usually referred to as a market economy of some kind.

They are constrained in what they do by the workings of the markets they can access. The goods and services available in these markets will determine whether the entrepreneur will be able to cover all expenses by revenues from fish farming operations and make a profit. They will do so jointly with the presence of input suppliers and the buyers of their products. However, small-scale farmers/entrepreneurs will always have to live with input and output prices over which they have little control (this is less the case for large operators). Prices may be modified by public interventions in the market, but seldom to the extent that they will cease to constitute constraints from the point of view of an individual aquaculture entrepreneur.

It is natural for fish farmers to feel constrained by the market. They would like to be paid more for their product and to pay less for the goods and services needed to run their fish farms. However, in an open-market economy, "price constraints" of this type will always exist.

However, markets are seldom perfect – in the sense of always allocating all resources where they provide the best results. Thus, public administrations may want to intervene. However, they generally do so after considering the effects on the economy as a whole and not on aquaculturists alone.

The market economy is no guarantee that all constraints, not even those that are microeconomic in nature, will be overcome or removed. The aquaculturist, or potential aquaculturist, may encounter as absolute hindrances a lack of suitable farm locations, a lack of manufactured fish feed of a certain quality or a lack of hatchery-produced fish seed.

Feed is perhaps the best-known constraint. In the 1980s, there were already discussions about the possibility of aquaculture development being slowed by a shortage of fishmeal and fish oil. However, 25 years later, it is clear that such a shortage has not been an absolute block for fish and shrimp farming. Indeed, growth in aquaculture continues to be impressive compared with that in other food-producing sectors. Thus far, fishmeal has been less of an effective constraint than many feared. However, given the difficulty in replacing fish oils, particularly in feeds for salmon, it is clear that competition for fish oil is likely to be a more serious obstacle for some sections of the aquaculture industry (Box 14).

Seed remains a constraint for many. In recent decades, aquaculture has grown rapidly, partly because this constraint was removed for some species through artificial reproduction (carp, shrimp and salmon). However, many aquaculturists still depend on wild-caught fry (or wild-caught broodstock). They include eel farmers in Europe and East Asia, most yellowtail farmers in Japan, grouper farmers in Southeast Asia and farmers of yellowfin tuna in the Mediterranean and off Australia. Thus, fortunes vary and will probably continue to do so. For many potential aquaculturists, the laws of nature, transmitted through the market mechanism, still place a definite limit as to which species can be cultured where and in what quantities. However, for some species, these laws are lenient and culture is easy, cheap and possible in many locations (e.g. whiteleg shrimp).

The market is also able to constrain entrepreneurs in other ways. Farmers who wish to expand their enterprises, and those who want to emulate successful colleagues and start fish farming, may find *inter alia* that:

- there is a lack of suitable coastal waters for fish farming (e.g. cage culture of marine finfish in China);
- there is not enough freshwater for fish farms (e.g. in Egypt);
- there is not enough land for culture sites (e.g. ponds for shrimp farming around the Bay of Bengal);
- tenure is not secure for water and/or land that is otherwise available.

In the extreme situation, a complete lack of access to culture sites or vital farming inputs may prove an insurmountable obstacle. However, often, access is possible but in another location, perhaps in another country, and often at a higher price than that paid by established entrepreneurs. The price difference may be sufficient to prevent expansion or the entry of new entrepreneurs.

However, in spite of all the valid reasons for having a market where prices are established through the interactions of so many that none has a decisive influence, fish farmers will experience them as constraints. Hence, it will be in the interest of governments to inform fish farmers about the importance and rationality of the market mechanism in order to redirect their attention to constraints that are more amenable to intervention.

As almost all the infrastructure and public goods available in an economy are not specific to aquaculture, governments that see aquaculture as important will ensure that representatives of the aquaculture industry can make their voice heard in the economy. This will be especially important in respect of economy-wide infrastructure projects but also in ensuring equivalence in conditions for national and international aquaculture entrepreneurs.

Box 14

Fishmeal and fish oil – the unpredictable long term

The world price for fishmeal remained between US$500 and US$700 per tonne in the period 2000–05. In 2006, it reached US$1 400. It has since remained above US$1 000 per tonne. The price of fish oil has also risen dramatically (see Part 1, Figures 39 and 40). Will these trends continue?

These prices result from the interaction of demand for fishmeal and fish oil (primarily from the aquaculture and livestock markets in all corners of the globe) with the supply of fish as raw material. The raw material is supplied by large dedicated fisheries and by other fisheries that supply retained non-targeted catch. Such fisheries are found in all the main oceans.

Much is happening in both the fishmeal and fish-oil markets. Aquaculture's share of fishmeal and fish oil has been growing. In 2006, this sector absorbed 56.0 and 87 percent, respectively, of world supplies. Fish and shrimp feed producers, who have seen their production costs rise, are trying to escape from dependence on fishmeal. Some success has been achieved – salmon diets now contain 30 percent fishmeal instead of the 50 percent of some years ago.[1] However, given the available commercially-adapted fish and shrimp feed technology, the demand for fishmeal from aquaculture is set to increase in the near future. In the longer term, demand will depend on the success of scientific research in reducing the use of fishmeal in fish and shrimp feeds. The global market will also be conditioned by future demand from the livestock sector and other users.

The supply of raw material for fishmeal has always fluctuated. Variations in oceanic conditions off the coast of Peru and farther out to sea mean that each season's landings of anchoveta for the fishmeal industry can differ in volume by more than 30 percent from that of the previous season. For example, in the El Niño year of 1998, anchoveta production

Knowledge constraints

Managerial constraints exist where farms are not run according to best farming practices. Best practices should *inter alia* result in:

- attaining satisfactory pollution and fish health standards;
- respecting food safety and hygiene standards;
- respecting market standards in terms of quality;
- a rate of return on investments and effort that makes the farm financially and economically sustainable.

Knowledge obstacles are often "hidden" in the sense that producers may be only partially aware of them. However, all of them can be overcome, and here the producers themselves have a large role to play. In collaboration with public authorities, fish farmers can improve their managerial performance significantly if they are made aware of their deficiencies and helped to remedy them.

Managers often consider microeconomic constraints to be the difficult ones. Having once overcome these, managers in more than one nascent aquaculture industry have not paid sufficient attention to the parameters governing the survival and health of cultured animals. Hoping to recover investments rapidly, they have increased stocking densities beyond recommended biosecurity levels (or beyond ecosystem resilience levels) with disastrous results. This happened in early Latin American shrimp culture, where such practices led to white-spot disease in Ecuador and Panama and long-term decline of the industries.

was 1.2 million tonnes (5.3 million tonnes in 1997). It went down from 8.6 million tonnes in 2002 to 5.3 million tonnes in 2003 (FISHSTAT statistics). While interseasonal variations may not be as drastic in other fisheries supplying raw material to fishmeal plants, global production volumes of fishmeal have fluctuated between 5 and 7 million tonnes irrespective of variations in demand for the final product (FISHSTAT statistics).

However, it is not only oceanographic variability that affects the supply of fish for fishmeal and fish-oil production. There are also competing uses for the fish. In the immediate future, there may be an increase in supplies. This would follow on from the rise in revenues of fishmeal plants. Following the increase in the world price of fishmeal, plants can afford prices much higher than US$100 per tonne for the raw material, which would have been unthinkable for most plants not long ago. In the immediate future, this will lead to a more intensive fishery of stocks already exploited for fishmeal, and the fishing of stocks not previously used as a source of fishmeal. Where small pelagics and miscellaneous non-target species are the food of the poor, the pressure for increased fishmeal production will create considerable controversy. Some will argue that, instead of using the fish for fishmeal, a larger share should be destined for human consumption. Such debates will be settled through political processes, the outcomes of which are virtually impossible to foresee.

[1] M. Klinkhardt. 2007. The blue revolution – feed alternatives for aquaculture. *In* FAO. *Global Trade Conference on Aquaculture, 29–31 May 2007, Qingdao, China*, edited by R. Arthur and J. Nierentz. FAO Fisheries Proceedings No. 9. Rome.

Managerial constraints are not permanent in nature. Generally, manager-owners are keen to improve farm management practices, and there is a continuous evolution of practices. In areas where aquaculture is well established, specialized expertise is often available to help deal with these issues, but it may be expensive to access.

Managerial constraints are frequent and generally slow to be overcome in regions where fish farming is not a common practice and where little private industry or government-sponsored expertise is available.

A lack of technical expertise can act as a constraint in both the short and long run.

In the short run, access to off-farm technical expertise is essential if aquaculturists are to neutralize production constraints. The need for expertise varies with the farming technology used. On the one hand, farmers engaging in simple rural pond culture may only need to discuss matters with an aquaculture generalist with knowledge of on-farm fish feeds and fish reproduction. On the other hand, farmers running modern cage or pond units producing for international markets will need access to advice from specialists in fish pathology, nutrition, feed, reproduction, etc.

In the long run, technical innovations are essential for the continued growth of the aquaculture sector. Gradually, management practices will be refined by the farmers themselves, as many of them will experiment carefully in their production units. However, fundamental breakthroughs in areas such as artificial reproduction, disease control and the use of improved feed will be achieved off-farm in laboratories run

by private industry, universities or state-run research and development centres. The building and staffing of such facilities take considerable time.

However, it is not only those at the forefront of aquaculture development who need scientific expertise in order to overcome knowledge constraints. Science-based understanding of aquaculture is equally important in regions were the sector is small or about to develop. Resident scientists in these regions should receive technical developments, adapt them to local conditions, and participate in disseminating the results to local farmers and entrepreneurs.

That said, technology transfer is not automatic even in regions with much aquaculture. Up to 75 percent of aquaculture production comes from millions of small-scale farms, most located in Asia. Although input and service providers act as conduits for transferring knowledge, given the large number of farmers, governments may find it advantageous to help farmers to organize themselves into clusters (Box 15). This will facilitate the flow of knowledge between scientists and farmers, and it will also promote adherence to best aquaculture practices if farmers are allowed to self-manage and self-regulate within clusters.

Governments that see aquaculture as important will probably place increasing emphasis on helping to neutralize the constraints caused by deficient fish-farm management and the lack of technical expertise in subjects relevant to the industry.

Social constraints

As most other agricultural or livestock activities, aquaculture affects the lives of individuals who are not directly engaged in the industry, and negative externalities occur. The most well-known effects are pollution and ecosystem disturbances originating from aquaculture production units. In some tropical coastal regions, shrimp farming has had a negative impact on marine and terrestrial environments. In some developed economies, the wider public has resisted cage culture not only because of the pollution risks but also because cages have been deemed to spoil the view.

Governments have intervened to heed these and similar concerns by regulating when, where and how aquaculture can be undertaken. Interventions started out mostly as "command and control" policies. Over time, these policies have been refined through the introduction of economic incentives and disincentives. Examples are pollution fees, environmental taxes and tradable permits. From the point of view of the entrepreneur, these regulations constitute constraints.

Such guidelines are often subjective in nature. However, unless they produce for export, aquaculturists are unlikely to face severe public regulations in economies where few regulations apply to natural-resource-based industries or activities. In these cases, the producer will have to satisfy the public and/or private standards that apply in export markets. Guidelines are likely to be more demanding in wealthy industrial economies where most economic activities are regulated in order to reduce pollution and other negative externalities. Also, where aquaculture is important for food supplies and local economies, standards are less severe than in areas where aquaculture is insignificant, which is the situation in several developed economies.

As governments regulate externalities, existing farmers are likely to face increasing costs. In order to limit such consequences, and to increase the political possibility to regulate, governments will find it advantageous to make clear to potential aquaculturists, as early as possible, their intention to regulate (as well as the legal status and the purpose of future regulations).

Farmers will generally experience aquaculture regulations as constraints and essentially be "against" them. However, in addition to regulating aquaculture, public policies can help overcome constraints that may not be apparent to those participating in nascent or rapidly expanding aquaculture activity. Constraints "hidden" to a nascent industry can include any and all of the knowledge and market constraints discussed above. Proactive public policies for aquaculture will ensure development of a strategy to help entrepreneurs overcome these obstacles when they occur.

Box 15

Globalization – obstacle or opportunity for small-scale fish farmers?

Developing countries account for about 50 percent of fish exports. A large share of this originates in the small-scale sector. This means that market access requirements in importing countries, in particular those on quality and safety, have direct implications for small-scale fish farmers, for their production and for their economic well-being.

One might argue that, because of globalization (e.g. improved communication technology and mobile-telephone networks), the world is becoming one and indivisible as far as fish and fish products are concerned, and that, therefore, the actions of small farmers are determined by what happens globally. In some measure, this may be so.

However, it is not a practical reality for most small farmers in developing countries. While they suffer or benefit, with more or less delay, from developments in the rich industrialized world, most have only a vague notion of the source and reasons for their changing circumstances. The vast majority see their livelihoods as determined above all by what goes on in the region or country where they live and operate.

Few farmers have the time and energy needed to learn about foreign markets on their own. One way of reaching out to small-scale farmers and helping them adapt to the world outside is through the use of clusters. This has had considerable success in many countries, for example, through certification of small-scale operators organized in clusters of five producers at a time. As the farmers involved have seen their yields and economic returns increase, other farmers have come forward to join in. The effect has been that thousands of small-scale fish farmers have obtained certification of their production and, thereby, gained better access also to international markets.

Globalization can also constitute an opportunity for small-scale farmers, and the better they understand the phenomenon, the better equipped they will be to exploit this opportunity. Understanding the influence and the possibilities of distant markets and societies will prepare them for necessary changes.

Small-scale farmers need the support of the public sector. As farmers become more informed about globalization and its effects, what could be an obstacle can be turned into an opportunity.

Knowledge constraints are of particular importance in this context. They can create havoc in an aquaculture industry. Moreover, it takes time to build up local expertise in aquaculture-related sciences for which academic institutions are few and the science itself evolving.

Fish genetics and fish reproduction fall into this category. The benefits achieved through selective breeding are remarkable, but probably not known to most small-scale farmers in the developing world. In a recent report, the World Bank[4] presents data indicating that selective breeding in salmonids, channel catfish, tilapia, carp, shrimps and bivalves yields increases in growth rates generally above 10 percent per generation, and that this has been sustained over several generations for some species (tilapia and salmonids). All else being equal, such improvements in growth rates enable cost reductions (without reducing production), and this expands the markets for the cultured produce.

THE GLOBAL CONTEXT OF AQUACULTURE GROWTH – IMPLICATIONS FOR CONSTRAINTS

In the second half of 2007 and early in 2008, energy costs and the prices of basic foodstuffs rose rapidly worldwide. This also affected fish prices – particularly those for wild-caught fish – which rose in real terms for the first time in many years. These increases will affect demand for fish, which is likely to suffer a setback in 2008 and 2009. However, there is no reason to believe that the rise in the retail price of fish will lead to permanent modifications in relative prices (*vis-à-vis* red meat or other substitutes). Therefore, by 2010, global demand for fish and fish products will probably continue to increase following the pattern of recent decades.

When demand growth for fish resumes, it could be satisfied if fish supplies for human consumption increased by between 1.2 and 1.5 million tonnes per year (see note 2). This amounts to an annual growth in fish supplies of between 1.1 and 1.4 percent in volume terms.

Most of this increase in demand will be caused by population growth; the remainder will be the result of gradually rising disposable incomes, particularly in developing countries.

However, the likelihood that supplies will grow at this pace differs from region to region. Some regions (North America and Western Europe) have stagnant demand and are likely to experience little economic difficulty in maintaining per capita supplies even if landings from capture fisheries fall. However, other regions, especially sub-Saharan Africa (SSA), could experience radically different scenarios. The remainder of this section reviews the scenarios for aquaculture development and the implications for growth constraints in eight geographical areas. As international trade links one region to another, what happens within the regions is also determined by what happens outside them.

The scenarios[5] are very approximate. They are developed only to the extent needed in order to provide a background for identifying market forces that might drive aquaculture in a region and, hence, provide an idea of the future types of aquaculture products and their markets. In turn, this will generate ideas about the nature and importance of the constraints confronting the aquaculture sector in the region. The purpose of developing scenarios is to derive conclusions about the situation confronting aquaculture that may serve as the starting point for the development of public policies to improve the possibilities for sustainable aquaculture by overcoming constraints. As such policies are implemented, the scenarios will be modified, and *ex-post* reviews should reveal that the scenarios, as described here, did not materialize. Thus, the scenarios should not be mistaken for "predictions of history". They are only the means to an end: better aquaculture polices.

Sub-Saharan Africa

It seems that the population of SSA would buy more fish if they had the economic means to do so. In the immediate future, given the overall rise in food prices (which will probably spread also to fish), this is unlikely to happen. However, in the medium to long run, it is probable that demand will grow rapidly. There are three main reasons for this: (i) continued rapid population growth (exceeding 2 percent per year); (ii) reasonable economic growth; and (iii) the nutritional importance of fish in the African diet. However, in the next decade, neither domestic production from capture fisheries (marine and freshwater) nor local aquaculture will be able to provide the increased quantities of fish needed for human consumption. A part of this need may be satisfied through increased imports of low-value species.

Demand growth

It seems plausible that, by 2015, total annual fish consumption in SSA could be 1.5–2.0 million tonnes higher than in 2005 if fish supplies expand at an equal pace with demand.[6] This would result from a yearly increase in the volume of fish consumed of about 3 percent in volume terms. In relative terms, this is a larger increase than that foreseen for any other comparable region of the world.

Some 70 percent of the growth in demand comes from an increase in population, which means that demand growth is steady and large. Depending on the economic situation of the region, it could increase dramatically for two fundamental reasons. First, as mentioned above, the high nutritional significance of fish products (given the relatively low levels of red-meat consumption) implies that public policies should favour the supply of cheap fish. Second, for the same reason, the income elasticity of demand is likely to remain high. Therefore, any increase in the rate of improvement in economic well-being could reflect directly in a significant increase in the demand for fish.

While fish is important in the African diet, it is neither an inferior good nor a luxury item. There are several countries in Africa where fish protein accounts for more than 30 percent of all animal protein consumed. Thus, there are good reasons for governments and the international community to try to ensure conditions that will permit African households to at least maintain their present fish consumption.

It is the average poor Africans who will account for the bulk of the population increase. Given the low economic growth postulated, there will be little if any growth in demand for luxury fish products. Demand growth is likely to be spread geographically and not be exclusive to urban areas.

Satisfying annual growth in demand

Overall, it does not seem reasonable to expect capture fisheries off Africa's coasts – or in its main lakes and rivers – to yield the growing volumes of fish (almost 0.2 million tonnes per year) demanded by a growing African population in the coming decade. In fact, in volume terms, SSA has been a net importer of fish for some time. Growing local demand will tend to increase this trade gap by pulling in more imports and retaining for local consumption some of the fish now exported.

However, it cannot be taken for granted that such changes in the international trade in fish will suffice to provide the increased quantities. There are difficulties. On the one hand, Africa is already an importer of large volumes of fish of low commercial value. The demand for this fish will increase worldwide both for human food and as raw material for making fishmeal and fish oil. This may bring international prices to such levels that African countries could only afford a limited quantity of that currently imported. The resulting demand for this category of fish by African consumers will depend on the relative increase in its price and the region's economic growth (purchasing power). On the other hand, fish that are now exported are generally sold abroad at much higher prices than they would fetch in most African markets. It seems unlikely that exporters will be willing to divert supplies to local markets as, in most cases, it would means less income for them.

Small pelagics off northwest Africa are a potential source of food. Increasing supplies of these species is not so much a technical problem as an economic one. The fish can be caught; the issue is whether they can be sold as a source of human food at a price that is interesting for producers.

The possibilities for aquaculture

Aquaculture in SSA will grow (Box 16), but probably not as fast as the market could absorb. Aquaculture for export markets will be spearheaded by international companies, while aquaculture for the national markets will be led – as now – by local, small-scale entrepreneurs.

As international aquaculture producers establish themselves in Africa, most will do so intending to supply markets in Asia, Europe and North America. Primarily, they will be interested in raising freshwater fish, with some interest in marine crustaceans and marine finfish. They will import the production inputs not available locally and, generally, export their products. Thus, at most, they will have a minor role as a supplier of fish for African consumers.

Small-scale local entrepreneurs will probably continue to expand supply at a rapid rate. They will produce tilapia, catfish and possibly other species well known in rural African markets. In volume terms, supply increases could exceed 10 percent per year. However, even at such a rate of expansion, they will only be able to contribute some

Box 16

Aquaculture and Africa – how to stimulate growth

Aquaculture is a growing investment across Africa and the subsector is currently expanding – in some countries, at a rapid pace. The 2005 FAO Regional Review of Aquaculture in Africa identified rising fish prices resulting from declining catches as a major stimulus for increased investment in aquaculture (FAO, 2006a). Improved prospects for profits are increasingly being realized by significantly revised approaches to aquaculture development. These new approaches emphasize much more private-sector involvement, with government acting less as manager and more as facilitator and monitor (FAO, 2006b). They have been integrated into the overarching Special Programme for Aquaculture Development in Africa (SPADA). The programme follows closely the priorities set by The New Partnership for Africa's Development (NEPAD) Action Plan for the Development of African Fisheries and Aquaculture (2005). It represents the FAO Fisheries and Aquaculture Department's strategic approach to addressing aquaculture development in its member countries in Africa. The goal of the SPADA is to improve economic and rural development by enhancing fish supply and distribution as well as benefiting nutrition through increased aquaculture production. This goal is to be achieved by promoting sustainable aqua-businesses at national level including the necessary public and private support services. The SPADA aims to:

- increase aquaculture production in the Africa region by at least 200 percent in the next decade;
- assist two-thirds of the countries in the Africa region in elaborating and implementing national aquaculture development strategies, with accompanying aquaculture plans, legislation and regulations;
- implement the Code of Conduct for Responsible Fisheries and best management practices as they relate to aquaculture, as well as institute monitoring and evaluation methods that ensure social and environmental soundness;
- strengthen the African Aquaculture Network to facilitate information exchange, provide technical assistance, coordinate education and research, and provide basic support to the sector while employing the latest information technology (including communications technology to facilitate networking and information exchange);

2.5–5 percent (5 000–10 000 tonnes of additional produce) of what is needed. By 2015, the annual increase in production may have reached 20 000–30 000 tonnes, but this would still be far below the potential growth in supply that the projected increase in demand could absorb.

Effective constraints

There are several operational aquaculture constraints in SSA, but they apply almost exclusively to local entrepreneurs. As many of the export-oriented firms are likely to be joint ventures between Asian entrepreneurs and local interests, the inherent African constraints on this type of activity (in the areas of management, farm technology expertise, and high-quality seed and feed) will be overcome through imports of whatever is not locally available. Thus, once established, these firms will not be held back by local constraints.

- facilitate access to inputs (e.g. feed, seed, capital, land and water) by investors while promoting intraregional trade and markets for aquatic products.

The programme will provide assistance at all geographic and administrative levels. It will be active in seven arenas:

- strengthening regional, subregional and national institutions;
- networking and outreach;
- capital and input supply;
- processing and marketing;
- research and education;
- social, economic and environmental soundness;
- monitoring and evaluation.

The programme is founded on the principle of promoting profitable and sustainable aquaculture through private–public partnerships. The application of approaches exemplified by the SPADA has already realized significant increases in growth in the aquaculture subsector in *inter alia* Kenya, Malawi, Mozambique, Nigeria, Uganda and Zimbabwe. Building on this track record, the SPADA is developing as a pan-African programme under a multilateral trust fund arrangement between FAO and donor countries and organizations to advocate and enable the expansion of responsible aquaculture across the continent.

Sources:

FAO. 2006a. *Regional review on aquaculture development. 4. Sub-Saharan Africa – 2005*, by T. Hecht, J.F. Moehl, M. Halwart and R. Subasinghe. FAO Fisheries Circular No. 1017/4. Rome.
FAO 2006b. *Guiding principles for promoting aquaculture in Africa: benchmarks for sustainable development*, by J.F. Moehl, R. Brummett, M.B. Kalende and A. Coche. FAO CIFA Occasional Paper No. 28. Accra, FAO Regional Office for Africa.
New Partnership for Africa's Development. 2005. *The NEPAD Action Plan for the Development of African Fisheries and Aquaculture*. NEPAD Fish for All Summit, Abuja, Nigeria, 23 August 2005.

However, from the point of view of an international investor, an aquaculture enterprise is an economic activity like any other. In Africa, the sector will have to compete for foreign capital, not only with other potential investments in Africa, but also with investment possibilities in other continents. This means that foreign-financed aquaculture investments in Africa will be made more readily in those countries with an internationally recognized record of good macroeconomic management than in those without such a record.

The situation is different for the small-scale, local, entrepreneurial sector. It is unlikely to develop as fast as the local market would want. Although access to suitable sites for ponds and cages may not constitute a major constraint, most producers will face other more serious constraints. The expansion of farming of freshwater fish in ponds and cages will be constrained by a lack of management expertise and technical skills. Moreover, there will be shortages of seed and adequate feeds.

In many parts of Africa, pollution has not been a concern of either farmers or administrators. This has been a rational approach given the prevalence of small units and low feeding intensity. However, as local entrepreneurs expand, using farm-made or industrially-produced feeds, and operations are intensified, pollution is likely to become an issue. The sooner local fishery and aquaculture administrations tackle this issue (*inter alia* through zoning and effluent management), the easier it will be overcome (and at the lowest cost for all concerned).

In strife-free areas with at least the rudiments of a market economy and an adequate infrastructure for communications and transport, the rate of aquaculture expansion will depend largely on how fast the public sector can ensure that up-to-date aquaculture research and development centres become functional.

Latin America

In respect of fish production and consumption, the situation in Latin America does not resemble that found in Africa. Latin America has a fish surplus, and its population generally prefers red meat to fish. Nevertheless, fish consumption per capita is somewhat higher than in SSA. However, it seems likely that this consumption pattern will change slowly, and that the average Latin American will eat more fish and less red meat. This development will be encouraged by the growth of modern distribution channels for fish as well as an increasing preference for health foods.

Demand growth

The projected growth in demand,[7] assuming supply will increase *pari passu* (at unchanged real prices), is relatively substantial. By 2015, the Latin American population may consume between 1.0 and 1.2 million tonnes per year more than they did in 2005 – an increase of more than 20 percent.

Some 60 percent of this increase will be generated by population growth. The share caused by income growth is relatively modest. This is not because disposable household income will not increase – it will – but because Latin Americans are assumed to continue to prefer red meat to fish. Thus, according to these exploratory calculations, by 2015, average per capita annual fish consumption in Latin America will have risen to 9.2 kg (8.7 kg in 2005).

Thus, in most of Latin America, with the exception of the population in the Andean mountain ranges, the growth in fish consumption is important more because it will stem from an increase in economic activity (capture fisheries or aquaculture) rather than because fish provides essential contributions to people's diet.

Satisfying annual growth in demand

At present, the annual increase in demand is estimated at 100 000 tonnes at most. This increase can be supplied from local fish landings if as little as 2 percent of the annual capture fishery catches of food fish is redirected to the local market. However, if this were to happen, real prices for fish would probably increase in both national and export markets by 2015.

With the exception of Brazil and a few small countries, Latin America is generally well supplied with marine fish, caught especially around the southern part of the continent.

However, the supply situation is not uniform. Coastal areas are generally very well supplied with high-quality marine fish. In the interior of Latin America, freshwater fish is highly appreciated but not in ample supply. Given the absence of large bodies of freshwater, freshwater fish are caught in the large rivers. However, the supply is limited, and it is difficult to envisage any substantial increases in supply either from improved fishing methods or better management of river fisheries.

In sum, the next decade does not seem to herald any difficulties for fish consumers in Latin America. They may be supplied with what they demand even if capture fishery production and aquaculture production remain at their present levels. However, real prices may be somewhat higher.

The possibilities for aquaculture

Aquaculturists in Latin America who want to supply the local market must be prepared to compete with capture fisheries that can produce volumes of fish far in excess of local needs.

Among the apparent opportunities for Latin American aquaculturists are local niche markets for local species and the international market for aquaculture staple products. However, in the long run, growth in the demand for fish will also result in growth for the aquaculture sector. The will be all the more so, the more successful the sector is in creating a recognizable profile among consumers.

Several species cultured in Latin America, particularly in Chile, are established in the international market. Will the aquaculture industry be able to expand their production too? The world market for trout can probably best be described as saturated, that for salmon as nearing saturation levels, and that for shrimp as growing but as uncertain. However, a saturated market is not stationary. It grows as does the economy of which it is a part. Hence, there will be some growth in the established aquaculture industries in the years ahead under most circumstances even if Atlantic salmon does not become a major item in the Chinese market.

A producer who is not satisfied with the status quo but wants to grow and sell more trout or salmon than economic growth would seem to allow – and does not see company takeovers as a way forward – will engage in what can be seen as a zero-sum game. An increase in market share for one producer, for whatever reason, will result in a loss for another producer. If the increase stems from real improvements in productivity and a resulting decrease in production costs, then, in the end, as this new technology or management practice spreads, everyone – including the consumer – will be better off.

Constraints

For aquaculture export industries, the main non-market constraints will be in the fields of farm management and fish culture technologies. Farms will continue to have better access to feed than most as Latin America is a large exporter of fishmeal and fish oil. However, as world prices for both fishmeal and fish oil are set to increase, the Chilean salmon industry may suffer more than entrepreneurs growing other species. This is because both feed ingredients are used in larger proportions in salmon feed than in most other fish or crustacean feeds. On the other hand, access to seed in well-established, export-oriented aquaculture is not a constraint.

The modern export-oriented industry will continue to have good access to developing technology. This will facilitate growth, as will public policies that adapt governance schemes to the new technologies and possible negative externalities.

The small-scale rural farmer with an interest in aquaculture will face constraints similar to those described for SSA. However, also outside the Andean range, governments will have incentives to use resources for aquaculture development, given the need to adapt new technologies to local conditions and to provide a science-based underpinning of industry regulations. Moreover, in several Latin American economies, urban-based entrepreneurs may take an interest in developing modern aquaculture operations to supply high-quality products to growing urban markets. They are likely to advocate and promote the development of local aquaculture research centres as a means to access required scientific expertise.

South Asia

Demand growth

On a per capita basis, fish consumption in South Asia is low at about 5 kg per year. However, its large population means that about 8 million tonnes of fish are consumed per year. Towards the end of this decade, consumption is likely to increase by between 150 000 and 200 000 tonnes per year if supplies are provided at present levels of real prices. In volume terms, this is an increase of slightly more than 2 percent per year. By 2015, total annual fish consumption may be some 1.5–2.0 million tonnes higher than in 2005.

Given that prevailing religious beliefs constrain consumption of red meats and fish in large parts of this region, about 70 percent of the increase in consumption will probably be generated through population growth. However, a decade from now, religious objections to fish as food may have waned and demand[8] increased. Moderate economic growth (some 2 percent per year) will nevertheless generate growth in per capita consumption, set to increase moderately from the 5.5 kg of 2005.

In certain coastal regions, particularly around the Bay of Bengal, fish is a significant source of nutrition in poor communities. Elsewhere in the region, it is less so.

Demand growth is likely to be spread throughout the various income categories. The expanding middle class is increasingly going to consume fish that is traded internationally.

Satisfying annual growth in demand

Apparent consumption in South Asia is well above that supplied by capture fisheries. The region is dependent on aquaculture for fish supplies.

Capture fisheries supplies have stabilized for the region as a whole. It seems unlikely that, in the next five to ten years, the capture fisheries sector could consistently increase its output to provide the amounts required to maintain per capita supplies. It would be even less able to contribute fish for food if there were an additional increase in demand caused by sustained economic growth.

For the region, international trade is not the apparent solution for maintaining supplies. The region is already a net importer. Local supplies will increase somewhat as a portion of what is now exported will be redirected to local urban markets. However, little of this fish will be economically accessible for the poor. Moreover, most of them will be unable to afford the prices of imported fish. Hence, a modified international trade pattern will satisfy only a part of the growing needs for fish.

The possibility for aquaculture

The situation described above implies that aquaculture will be the major source for satisfying the growing demand for fish in South Asia. Fortunately, freshwater fish culture is well established and supplying a popular product.

If aquaculture were to satisfy the full increase in demand for fish, the growth in aquaculture should be in the order of 4.3 percent per year in volume terms. Aquaculture in the region has grown faster than this in the last two decades: 10.1 percent in 1985–1994; and 7.0 percent in 1995–2004).

However, the question is whether the constraints on aquaculture are such that its growth in the decade 2005–2015 will fall below 4.3 percent per year.

Constraints

While there is a substantial shrimp farming industry in South Asia (producing mainly for external markets), there is little true mariculture. One of the main reasons for this is the geography of the subcontinent. There are few protected bays or lagoons for cage farming, possibly with the exception of those of Maldives and the Andaman Islands (India). These effective constraints are unlikely to be overcome before off-shore (possibly submerged) cage culture technology has developed. Local governments and industry do not have the strong incentive that those in North America or Europe have to develop such technology.

Aquaculture growth in the region will continue to be mostly in the form of freshwater fish culture. However, this will not be without problems. Both land and freshwater are increasingly in short supply. Small pond areas will favour culture of species that can be raised in high densities, such as catfish. However, the need to provide fish proteins as feed in one form or another will soon become an effective constraint for this type of culture by small-scale farmers. Those who increase the stocking rates of Indian major carps or Chinese carps will need to provide supplemental feeds, and energy for aeration and/or recirculation of water. Costs will rise and production expansion will slow.

It seems clear that public policies will focus on knowledge constraints. The selective breeding of carps and farm management in all its aspects are likely to become priority concerns in ensuring the continued growth of freshwater fish farming.

China

Demand growth

If fish supplies expand *pari passu* with demand, it seems likely that, by 2015, annual fish consumption in China could be 4.5–5.5 million tonnes higher than in 2005.[9] This would result from a yearly increase in the volume of fish consumed of about 1.4 percent. At the time of writing (July 2008), the annual increase is likely to be somewhere between 0.45 and 0.50 million tonnes.

The rapid economic growth in China coupled with a slow rate of population increase means that almost 60 percent of the increase comes from a projected growth in household disposable income. As annual per capita fish consumption in China at 26 kg (live weight equivalent) is already well above the world average (about 14 kg if China is excluded), it means that the growth rate is uncertain. Any change in the economic situation could reduce demand growth drastically. However, the pattern of fish consumption in China may change as increasingly affluent urban people turn away from what they perceive as low-quality products towards high-quality items. This would lead to lower growth in volume terms.

Satisfying annual growth in demand

China produces more fish than it consumes. This leaves the possibility of satisfying future increases in national demand by redirecting some of the products now regularly exported. Given the stagnation in capture fisheries production, the other way to increase production is through aquaculture.

The possibilities for aquaculture

In recent years, aquaculture production in China has grown in volume terms by 5–7 percent per year (about 2 million tonnes), significantly more than the projected annual increase in the volume of fish demanded.

China has the largest aquaculture sector in the world in terms of both the volume of aquatic animals produced and the number of species cultivated. This increases the likelihood that the sector will continue to be able to supply the local market with almost all that it will want. Some of the exotic species now in demand, such as Atlantic salmon, are not produced commercially by China's aquaculture or capture fisheries.

Constraints

Notwithstanding the foregoing, the possibilities for expansion are restricted. Reports from China say that the sites, goods and services needed by aquaculturists are also demanded by other actors in the economy – microeconomic constraints. Among these constraints are access to culture sites and availability of recurrent inputs, especially feed.

Freshwater fish culture and mariculture of molluscs and finfish are constrained by a scarcity of culture sites. Given current farming systems, the possibilities to overcome these shortages seem very limited. While research and development efforts will attempt to develop farming technologies that need less space and water, it seems plausible that Chinese aquaculture entrepreneurs will establish grow-out facilities abroad, particularly in SSA and Latin America. The added costs of transport (to bring products back to China) would be offset by lower costs for sites and recurrent inputs.

Pollution from inshore cages is a limiting factor. This is likely to continue to be an effective constraint on the growth of marine cage culture. In part to overcome this constraint, a considerable research effort is under way in China to develop off-shore and deep-water cage culture technology. However, the country's rapid economic growth, leading to an economy-wide increase in pollution, means that Chinese

aquaculture is being negatively affected. The pollution of both coastal waters and bodies of freshwater is reducing their suitability as sites for aquaculture enterprises.

A significant share of feed inputs is imported, in particular soybean, fishmeal and fish oil. Given the growing demand for fishmeal and oil (and the stagnating supplies of soybean), their price on the international market is likely to rise. An appreciation of the Chinese currency against the dollar may reduce the cost of feed and other imported inputs. However, this will probably not be sufficient to protect producers from rising costs, which in turn may slow the rate of aquaculture growth.

Southeast Asia

Demand growth

Consumption is high in absolute terms at about 18 million tonnes per year, more than double that of South Asia. By 2015, it could have increased by another 3 million tonnes, at an annual increase of between 250 000 and 300 000 tonnes if supplies keep pace with demand.[10]

Per capita fish consumption is high in Southeast Asia, and it is unlikely that continued growth in disposable incomes will cause more than a moderate increase in per capita consumption. Most of the increase in demand will come from population growth.

Satisfying annual growth in demand

Capture fisheries account for most of the fish consumed in Southeast Asia. Capture fisheries and aquaculture produce more than the region consumes, generating an annual exportable surplus of between 1.5 and 2.0 million tonnes. Although capture fisheries production is increasing moderately, it is unlikely to do so for long. Fisheries on wild stocks are reaching a limit also in this region.

Export volumes have grown but seem to have reached a plateau in the last three years. Accepting this trend as a general pattern, it seems unlikely that exports will grow significantly again (save for a sudden spurt in aquaculture production). Thus, for some time, a part of the capture fisheries production may be redirected to local markets. However, this would only cover a small share of the growing demand for fish in Southeast Asia.

The possibilities for aquaculture

In volume terms, aquaculture has grown at annual rates of 6.1 and 7.6 percent in the last two decades. As an overall demand increase of some 250 000–300 000 tonnes per year is equivalent, in volume terms, to about 4–5 percent of current aquaculture production, the continuation of present trends would seem to "resolve the problem". This means that the capture fisheries sector need not produce more for the local markets.

However, the question is whether the aquaculture sector will be able to produce this much more every year for the next five to ten years. If not, what obstacles will prevent it from doing so?

Constraints

On the one hand, aquaculturists in the region are part of vibrant, growing economies and, therefore, enjoy growing demand. On the other hand, this very success is generating obstacles in the form of increasing competition for culture sites and recurrent inputs. In addition, in foreign markets, those who feel unable to compete with imported aquaculture products from the region protest. Moreover, aquaculturists' increased dependence on wild resources is sometimes leading to unsustainable stress on wild resources.

It is evident that for some cultures (catfish, tropical spiny lobster, grouper, etc.), obtaining both broodstocks and feed from the wild will not be sustainable in the long run. As technology development is not proceeding sufficiently rapidly to overcome these problems through better hatcheries and feeds (farm-made or commercial), governments will need to intervene through regulations and enforcement. This will

subtract public resources from where they are most needed (in personnel training and technology development) and lead to slower development of the sector than might have been possible if the public sector could have concentrated fully on removing the knowledge constraints.

Europe, North America and Japan

Demand growth

On a per capita basis, Japanese fish consumption is the highest among the regions reviewed in this study, at slightly less than 60 kg per year. For North America and Europe, the corresponding quantities are 24 and 21 kg, respectively, both above the world average of about 16 kg. Combined, these developed economies consumed about 31 million tonnes of fish in 2005. Starting from these high levels, it is also necessary to consider: (i) a sign of falling per capita consumption in Japan (see Table 15); (ii) predictions of slowly falling populations in Europe and Japan; and (iii) slow to moderate economic growth for the three regions. Therefore, there will be very little, if any, increase in their combined fish consumption (in volume terms) between 2005 and 2015 as declining Japanese consumption is offset by growth in North America and a very slow increase in Europe. Thus, these three regions will consume slightly more than 20 percent of world supplies in 2015, down significantly from two decades earlier.

Satisfying annual growth in demand

Given the virtual stagnation in demand,[11] it could be expected that supplies will be made available. However, it cannot be taken as a given that capture fisheries in the region will continue to produce at present levels. Overfishing and deficient economic returns for fishing vessels may lead to a decline in effort. Neither should it be taken as a given that imports will continue at past levels. Economic growth in South Asia may cause some of the fish now exported to the industrialized world to be sold there instead.

The possibilities for aquaculture

In North America and Japan, aquaculture accounts for a minor portion of fish supplies, whereas in Europe it provides about 20 percent. However, it seems plausible that aquaculture in these three regions could expand to cover for shortfalls in capture fisheries, but it would probably face fierce competition from aquaculturists elsewhere (principally in Asia and Latin America).

It is a possible, but demanding, undertaking for aquaculturists in Europe, North America and Japan to make inroads in high-priced markets in Asia and Latin America. Thus, marketing, sales promotion and continued cost-cutting will be essential if aquaculturists in the developed world are to remain competitive.

In Europe, a segment of better-off consumers have much interest in what they eat (Box 17). There are those who prefer "slow food", or products with a regional affiliation certified by geographic denominations and labels. Such groups provide European aquaculture producers with niche markets to target through dedicated marketing efforts.

Constraints

The market for aquaculture products produced in the industrialized world will not expand rapidly at present price levels. At the current prices for salmon, trout, catfish and sea-bass, consumers in these markets seem unlikely to increase their consumption unless capture fishery supplies of similar products fall.

However, it is not unusual for agriculture commodities to pass through production cycles where the volumes produced first expand only to contract later. A frequent cause of such cycles is the time lag that occurs between producers' decisions to modify output and the subsequent effects on supply once produce is harvested. Generally, however, the long-run tendency for aquaculture products going through such production cycles, and the consequent rise and fall in volumes and prices, is one of increasing volumes and falling prices. Moreover, as production grows, the cycles flatten out.

Box 17

Balancing the risks and benefits of consuming seafood

The strong focus on contaminants in foods is increasingly attracting the attention of consumers who are becoming more aware of the potential health impacts of a contaminated food supply. Fishery products can be linked to contaminants such as methylmercury and dioxins.

The traditional focus has been on the risks of consuming potentially-contaminated foods. However, there is now a growing focus on the risks of *not* consuming such foods, given their potential beneficial components. Some studies have tried to balance the positive and negative sides of consuming foods of high nutritional value but which are also a source of contaminants. A recent study concluded that, for the Netherlands population, the health loss from consuming unhealthy food is about 100 times that from consuming chemically-contaminated foods.[1]

In general, the levels of contaminants such as methylmercury and dioxins in seafood are well below the maximum levels established. However, some fishery products from polluted areas or large predatory fish can sometimes exceed these levels.

This has persuaded some countries to issue advice on limiting the consumption of such fish, in particular for vulnerable groups such as children and pregnant women. While the intention was only to limit consumption of products known to have elevated levels of contaminants, the effect in some cases has been a significant reduction in seafood consumption. The target groups of this advice are heavily dependent on a nutritionally optimal diet to cover their needs for omega-3 fatty acids and iodine – essential in the early development of the neural system. Seafood is known to be the main natural source of these nutrients.

A more holistic approach is needed in order to give advice on balancing the risks and benefits of consuming fishery products. The existing focus on links between seafood and contaminants on one side, and between seafood consumption and health on the other, is making it increasingly relevant to provide advice to governments on how to handle such issues.

In this context, FAO and the World Health Organization are preparing an expert consultation on the risks and benefits of consuming seafood. The first phase would focus specifically on the impact of methylmercury exposure on women of childbearing age and the future development of their children with respect to neural and cardiovascular development as well as the benefits of fish and its components. The confounding effects, if any, of dioxin and dioxin-like polychlorinated biphenyls (PCBs) will also be considered, as dioxin intake is highly correlated with the intake of fatty fish, which are also significant sources of the beneficial omega-3 fatty acids.

[1] C.F. van Kreijl, A.G.A.C. Knaap and J.M.A. van Raaij, editors in chief. 2006. *Our food, our health. Healthy diet and safe food in the Netherlands*. Bilthoven, Netherlands, National Institute for Public Health and the Environment.

At present, technological constraints seem to be holding back expansion of cod and cobia culture. Recent increases in the real cost of energy will probably affect aquaculture in the industrialized world more severely than in the developing world. However, the relatively low incidence of transport costs in the price of the final aquaculture product means that the effect on international trade, and third-country processing, will be minor.

Thus, the individual entrepreneur who wants to expand aquaculture output rapidly needs to capture a larger share of the market. This can be achieved with a new species (cod or cobia) or where the new product may be sold at the expense of products already on the market (salmon and tilapia). Increasing market share can also be a matter of price competitiveness. However, the ability to maintain substantially lower prices than competitors usually requires culture technology improvements, or faster-growing or better-growing specimens compared with those generally used in the industry. Thus, the farmer has to overcome technology hurdles.

However, innovative farmers may also develop a superior business model, possibly obtaining cost advantages from integrated hatcheries, on-growing facilities and economies of scale in input procurement.

Despite the growing use of fishmeal and fish oil elsewhere, particularly in Asia, it seems unlikely that feed price increases will be large enough to reduce profit margins significantly in established industries at least in the next few years.

Aquaculture development in these three regions will be led by entrepreneurs. Governments will probably refrain from intervening in matters other than those caused by negative externalities linked to aquaculture and those related to "unfair" international competition. They will provide some support to technological development, but it is not likely to become a priority.

SUMMARY AND CONCLUSIONS

There is little doubt that worldwide aquaculture growth will slow, albeit with growth spurts for particular species and regions. The success of the industry is bringing out constraints that were only potential when it started to grow. These obstacles will not simply disappear. Persistent efforts will remove or reduce them, but then others will arise. However, it is equally true that aquaculture will continue to grow in response to demand for fish and seafood generally. It will not come to a standstill.

As aquaculture entrepreneurs – large and small, modern and artisanal – and governments increasingly collaborate to remove knowledge constraints (those they are best equipped to handle and those that yield the best returns for the effort), the aquaculture industry will start to reduce its dependence on wild stocks. Currently, its need for broodstock, seed and feeds slows development. Once this dependence has been reduced, the industry will start to benefit from gains similar to those long enjoyed by the livestock industry, in particular those of selective breeding.

NOTES

1. Unless stated otherwise, in this text, the term fish includes crustaceans and molluscs.
2. In order for the world average per capita supply of fish for food not to fall, the net annual increase in total supply must reach about 1.3 million tonnes, given the present per capita supply of 16.7 kgs and a world population growth of about 78 million per year.
3. FAO. 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*, edited by M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon. FAO Fisheries Technical Paper No. 497. Rome.
   FAO. 2007. *Assessment of freshwater fish seed resources for sustainable aquaculture*, edited by M.G. Bondad-Reantaso. FAO Fisheries Technical Paper No. 501. Rome.
   FAO. 2008. *Capture-based aquaculture. Global overview*, edited by A. Lovatelli and P.F. Holthus. FAO Fisheries Technical Paper No. 508. Rome.
   FAO. 2008. *Report of the FAO Expert Workshop on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and Its Implications to Food Security and Poverty Alleviation, Kochi, India, 16–18 November 2007*. FAO Fisheries Report No. 867. Rome.
4. World Bank. 2006. *Aquaculture: changing the face of the waters. Meeting the promise and challenge of sustainable aquaculture.* Report No. 36622 – GBL. Washington, DC.
5. The period considered in the scenarios is the decade starting in 2006. For each region, a scenario projects plausible developments in capture fishery production, international trade in fish, non-food use of fish and demand growth for fish. These are extrapolations of trends based on data from the UN (population), FAO (fisheries and aquaculture) and *The Economist* (economic growth). Trend modifications are described in the text. As a rule, the demand projections are conservative. The main reason is that income elasticities of demand are projected average elasticities for the decade and, thus, with the exception of SSA, well below the empirically derived elasticities generally valid for a short period. As disposable income increases, these can be expected to fall over time, especially for high-volume, low-value products.
6. For the period 2006–15, the average income elasticity of demand has been placed at 0.9 and the annual average growth in disposable real income per capita at 1 percent.
7. For the period 2006–15, the average income elasticity of demand has been placed at 0.4 and the annual average growth in disposable real income per capita at 2 percent.
8. For the period 2006–2015, the average income elasticity of demand has been placed at 0.3 and the annual average growth in disposable real income per capita at 2 percent.
9. For the period 2006–15, the average income elasticity of demand has been placed at 0.2 and the annual average growth in disposable real income per capita at 4 percent.
10. For the period 2006–15, the average income elasticity of demand has been placed at 0.3 and the annual average growth in disposable real income per capita at 1 percent.
11. For Japan, the income elasticity is negative, while for North America and Europe it has been placed at 0.3 and 0.2, respectively. Growth in average annual disposable real income per capita has been placed at 1 percent.

Please find enclosed a complimentary copy of the
World Fisheries and Aquaculture Atlas CD-ROM. The Atlas, now in its fifth edition,
presents a comprehensive and global view of marine and inland capture fisheries and aquaculture.
It is currently available in English only.

For futher information please contact the FAO Fisheries and Aquaculture Department.

THE STATE OF WORLD FISHERIES AND AQUACULTURE

2008

After growing steadily, particularly in the last four decades, aquaculture is for the first time set to contribute half of the fish consumed by the human population worldwide. This reflects not only the vitality of the aquaculture sector but also global economic growth and continuing developments in fish processing and trade. Until a year or so ago, production trends in aquaculture and capture fisheries were continuing without any drastic modifications – with the capture fisheries sector regularly producing between 90 and 95 million tonnes per year, and aquaculture production growing rapidly, albeit at a gradually slowing pace.

This issue of *The State of World Fisheries and Aquaculture* features some aspects of fisheries and aquaculture that may receive increasing attention. These include climate change, the use of marine genetic resources in areas beyond national jurisdiction, and the proliferation of private standards and certification schemes in the international fish trade. This report also highlights some of FAO's special studies. Among these are the use of wild-fishery resources as seed and feed in aquaculture, and reviews of the world's shrimp fisheries and of the management of marine capture fisheries in the Pacific Ocean.

Includes the fifth edition of the FAO *World Fisheries and Aquaculture Atlas* CD-ROM, a comprehensive and global view of marine and inland capture fisheries and aquaculture (available in English).

ISBN 978-92-5-106029-2 ISSN 1020-5489

9 789251 060292

TC/M/I0250E/1/10.08/2600