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GLOBAL AQUACULTURE OUTLOOK IN THE NEXT DECADES: AN ANALYSIS OF NATIONAL AQUACULTURE PRODUCTION FORECASTS TO 2030

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GLOBAL AQUACULTURE OUTLOOK IN THE NEXT DECADES:

AN NALYSIS OF NATIONAL AQUACULTURE PRODUCTION FORECASTS 2030

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PREPARATION OF THIS DOCUMENT

The Development Planning Service (FIPP) of the FAO Fisheries Department is the lead unit for the preparation of "The State of World Fisheries and Aquaculture", published bi-annually by the Fisheries Department. This document regularly includes a section dedicated to the outlook for the sector. This study, carried out between October 2003 and April 2004, provides information for this section.

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Comments on this document are welcome and should be directed to Chief, Development Planning Service (FIPP), Viale delle Terme di Caracalla, 00100 Rome, or through FI-inquiries@fao.org.

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ABSTRACT

Aquaculture production is expected to play a crucial role in forthcoming decades in compensating for stagnant capture fisheries and in meeting increased demand for aquatic products. Designed to ascertain the compatibility of national aquaculture production forecasts with the global prevision of the sector's growth to 2020 and beyond, the report attempts to answer three questions:
1) Do individual countries have the ambition to expand their aquaculture sector to meet global demand forecasts, and are their projections realistic?
2) Is the "sum" of national production forecasts compatible with global projections of anticipated requirements from the aquaculture sector?
3) What planning lessons can be learnt from examining individual country plans, and how could the process of aquaculture planning be improved?
Three global forecasts (Delgado *et al.*, 2003; Wijkström, 2003; Ye, 1999) were used as a benchmark against which countries' ambitions were assessed through an analysis of the contents of their national aquaculture development plans.
Results showed that the countries studied do wish to expand their aquaculture output and, with some exceptions, their assumptions were realistic as most governments appeared to endorse the sector's growth. Aggregation quantitative production targets from the national plans indicated that global forecasts may have underestimated the future supply of fish food coming from aquaculture. The future expansion of Chinese aquaculture remains critical but using a modest 2 percent annual growth rate and without increases in food fish output from capture fisheries, results suggested that most of the demand projections for fish would be met in three forthcoming decades. Thus, aggregated country productions from aquaculture are expected to grow at an average annual growth rate of 4.5 percent over the period 2010-2030. In terms of planning, appraisal of plans and strategies revealed a generally weak planning process as methodologies and procedures tended to be sketchily reported. A planning framework with issues to address is suggested with the back-up of a consensus-building technique such as the Delphi method to improve the quality of future plans and enable an evaluation of their likelihood of success, as transparency, legitimacy and agreement are key to the success of a plan.

CONTENTS

INTRODUCTION

Driven by rising real incomes and urbanization, apparent per capita consumption of food fish in the world, including China, reached 24.8 kg per year in 2001, almost five times that of 1961 (FAOSTAT, 2004), and this in spite of a rise in food fish prices, both in real and relative terms. The increase in per capita consumption, combined with population growth, has led to world consumption of food fish more than tripling over the same period. To meet the growing demand for food fish, supply has come increasingly from aquaculture. Production of food fish from the capture fisheries has increased by a slow 1.2 percent annually since the early 1970s, whereas output from aquaculture (even without China) has grown by an annual compounded rate of more than six percent.

Output from the capture fisheries will continue to grow slowly, if at all, so aquaculture must expand to meet growing demand for fish. Population growth, rising per capita incomes and urbanization are expected to fuel a growing demand for fish. According to the sanguine view that "if the past history of agriculture is any guide, aquaculture will surely find a way to meet the world's demand for fish" (*The Economist*, 2003, p. 21), technological advances, induced by higher fish prices, can replicate agricultural food production. Increased supply will come from expanding areas of cultivation (e.g. ponds and offshore cages) and higher yields per unit area (e.g. selective breeding and improved feed). However, as a relatively new industry, aquaculture also faces growth constraints. Environmental concerns and social opposition may inhibit its growth. These factors could prevent aquaculture from expanding sufficiently to meet demand without very large price increases, which, in turn, would have negative implications for the poor and their access to food.

Acknowledging the challenges the aquaculture sector may face in coming years to expand its production, and underlining the need for suitable development planning, the Twenty-fifth Session of the Committee on Fisheries established a Middle-Term Plan (2004–2009) which recommended that a "*global analysis of economic and social trends in fisheries and aquaculture*" be carried out in order to "enhance international and regional collaboration based on a more accurate and common understanding of long-term trends and emerging issues" (p. 21).

One means of judging whether forecasts of aquaculture expansion are realizable is to study national aquaculture plans. With their expected future aquaculture output, national plans can be aggregated to see whether they are compatible with general equilibrium forecasts. By providing insights into future directions, they are also indicative of national production ambitions, which realism can be assessed through a close examination of underlying production assumptions and their economic and environmental implications.

It is not the task of this study to make new supply and demand forecasts for fish products, this type of analysis having already been done by a number of scientists at a global scale (their findings are detailed in section 2.1). Instead, this study focuses on national aquaculture development plans and individual country's production forecasts whilst using the global projections made from independent organisations as a benchmark against which to measure the realism and relevance of forecasts and assumptions underlying them. Over the last ten years, a recurrent question has been: "can aquaculture fill the gap?" (Ruckes, 1994). Yet attempts to answer it have come mainly from the analytical efforts of experts in the field, at a global level, and without much consideration to producing countries' ambitions and capacity to contribute to filling the future fish demand gap. This study aims to rectify this oversight by investigating aquaculture producers' endeavours. Individual country plans will not be compared to one another, nor their contents and results critically judged, but rather placed in a global context of aquaculture development that requires suitable planning, to both fulfil expectations and occur in a coordinated manner.

The report attempts to answer three questions:

1) Do individual countries have the ambition to expand to meet global demand forecasts, and are their projections realistic?
2) Is the "sum" of national production forecasts compatible with global projections of the sector's growth – i.e. will this sum match projected increases in demand for food fish? – raising the additional question of "who's projections are most accurate?"
3) What planning lessons can be learnt from examining individual country plans, and how could the process of aquaculture planning be improved?

Findings from this study aim to shed light on medium and long-term development policies necessary to ensure the sustainable contribution of aquaculture to aggregate fish supply, and therefore, to meeting national and world demand for fish and fishery products.

The report is structured around the investigation of each question, after the methodological approach adopted for the study is presented. The first section will explain the methodology adopted and the countries selected. The second will answer questions 1 and 2 above by analyzing individual countries and regions within the context of global forecasts. A final section attempts to learn from the plans "best practices" to support policy-makers in the future formulation of accurate aquaculture development plans.

1. METHODOLOGY: APPROACH AND CONSTRAINTS

1.1 Selection of countries, collection and analysis of national information

The determination of countries to be included in the sample was initially aimed at ensuring the representation of major producers from all continents (Box 1), and to take into account the production of low value fish in low income food deficit countries (LIFDCs) (Box 2). A list of the 18 major aquaculture producers, totaling a production of 35.7 million tonnes (94.4 percent of world aquaculture output, 82.2 percent excluding China) was thus compiled from a review of individual countries' contribution to global aquaculture production (Table 1).

In-house information was collected and government officials in fisheries/aquaculture authorities of the above mentioned countries were contacted to request their latest national strategies, plans and forecasts for aquaculture production. With an expected variation in the duration and time-scale of plans, the year for production targets was left open. With a somewhat limited response (not all countries have strategies and development plans for their aquaculture sector and many are currently elaborating them) and delays occurring in the reception of such documents, the sample had to be reduced to those countries for which quantitative aquaculture production projections and targets were available from government sources[1]. A total of 26 plans and strategies were obtained, out of which 11 contained the

[1] Other sources (from academia) were found but it was decided not to include them in the analysis of the plans as they may have not reflected the motivation and ambition of countries to develop aquaculture. An exception to this is Egypt for which the only document obtained was written by ICLARM (currently known as the WorldFish

quantitative information required for the study. These 11 countries are today's main aquaculture producers (Table 1), representing 86.5 percent of the world aquaculture production in 2001, thus not compromising the representativeness of the sample.

Box 1: Main aquaculture producers by region in 2002
Figures in brackets indicate production in tones (excluding aquatic plants).

ASIA: China (27 767 251), India (2 191 704), Indonesia (914 066), Japan (828 433), Thailand (644 890), Bangladesh (786 604), Viet Nam (518 500), Philippines (443 319).

AFRICA: Egypt (372 296), Nigeria (30 663), Madagascar (7 966)

SOUTH AMERICA: Chile (545 655), Brazil (246 183), Mexico (73 675), Ecuador (70 181) and Colombia (65 000)

NORTH AMERICA: USA (497 346), Canada (172 336).

EUROPE: Norway (553 933), Spain (263 762), France (249 699), Italy (183 962),
UK (179 036), Greece (87 928).

Source: FishStat Plus, 2004.

Box 2: Main countries producing low value fish in 2001

FISH SUPPLY IN LOW INCOME FOOD DEFICIT COUNTRIES (Low value fish rather than high value finfish):

CHINA
INDIA
INDONESIA
THAILAND
BANGLADESH
VIET NAM
PHILIPPINES

Source: FAO Yearbook on Fisheries Statistics, 2001.

Center), but, representing the African continent, it was nevertheless decided to maintain its inclusion in the study. Documents from government sources were received in various forms, including power-point presentations.

Table 1: Selected countries based on contribution to global aquaculture production in volume (top 18). 2001 figures

Countries	Percent of global volume	Quantitative projections available
China	68.8	YES
India	5.8	YES[2]
Indonesia	2.3	YES
Japan	2.1	NO
Thailand	1.9	YES
Bangladesh	1.8	YES
Chile	1.5	YES
Viet Nam	1.4	YES
Norway	1.4	NO
USA	1.2	NO
Philippines	1.1	YES
Egypt	0.9	YES
Spain	0.8	NO
Taiwan (Province of China)	0.8	NO
Korea	0.8	NO
France	0.7	NO
Italy	0.6	NO
Brazil	0.6	YES
Additional country:		
Canada	0.4	YES

Source: FAO Yearbook on Fisheries Statistics, 2001.

1.2 Framework for analysis of the contents national aquaculture development strategies and plans[3]

As planning methodologies, assumptions and contents of individual plans varied markedly from one country to the next, each document was assessed against a standard and broad framework, outlined below (Box 3). The framework criteria, inspired from the structure adopted in the Chilean development plan for aquaculture, were chosen to map out the contents of each document in a systematic way.

[2] The Indian plan concerns freshwater aquaculture development only. Yet, this sub-sector represented 37% of the total fish production of the country and 94% of the total aquaculture production in 2001.

[3] Countries were requested to provide any relevant document they had in their possession regarding their envisioned development/expansion of aquaculture. However, the distinction between an aquaculture development *strategy* and an aquaculture development *plan* should be kept in mind as these two documents do not contain the same type of information. The importance of this distinction in planning activities is highlighted in Section 4.

Box 3: Framework of analysis of national aquaculture strategies and plans

1. Time frame of the strategy/plan
2. Methodology used for the forecasts
3. Present situation of aquaculture development
4. Forecast by species
5. Assumptions used:
   - Prices
   - Markets
   - Environment
   - Regulatory
   - Development/ Promotion
6. Principal threats / constraints to overcome

1.3 Evaluation of existing global forecasts (supply and demand) and realism of assumptions for national aquaculture production forecasts

A search of the literature yielded a number of references on anticipated trends and future demand and supply for food fish in forthcoming decades. The formulation of these different sets of projections was analysed and constituted the benchmark against which the realism of national forecasts could be assessed in terms of:

- Profitability – have considerations of markets, consumer preferences and price variations been included in estimates of profitability and potential from envisaged aquaculture operations?
- Technical issues – are technical developments envisaged and choices made congruent with past experience, resources and expertise available in-country (e.g. increases in productivity or increases in space use, diversification versus intensification, high-value versus low-value species, etc.)?
- Constraints – have potential limitations to the activity, of an environmental (e.g. coast line or inland water resources availability, environmental sustainability), economic (e.g. capital and investment) or/and social (e.g. past conflicts over resource use) nature been taken into account in the projections?
- Performance – how do past growth rates of the activity compare with those envisaged?

1.4 Comparison of the "sum" of national forecasts with global projections

The analysis of global forecasts allowed quantification of the quantities required from aquaculture to fill the fish demand gap in the years 2010, 2020 and 2030. Production targets presented in national plans were then summed up, under various scenarios, and compared with global projections of future requirements from aquaculture and specifically answer question 2. Some assumptions on behalf of the authors in manipulating data were necessary. Details of calculations are given where necessary to explain and justify the reasoning behind the analysis performed in Section 3.

1.5 Planning lessons

The detailed examination of country plans and strategies was also indirectly used to evaluate their thoroughness and planning methodologies adopted. It triggered reflections on the wider lessons that could be learnt from the evaluation exercise. These issues have broadened the scope initially envisaged for the study and are explored in more depth in section 4 of the report which presents a list of key factors to make a “successful” plan.

1.6 Limitations of the study

This study was ambitious, especially given the time imparted and the delays faced in the gathering of documents from country governments. With the range of documents collected (from qualitative – visionary – frameworks to quantitative production targets for aquaculture), the analytical assessment of the documents contents was not easy, and their interpretation rested, ultimately, with the authors. As the study will show, a number of different sources were consulted for global forecasts on the future of the sector. Expectedly, these differed from one another as they reflected various methodologies and assumptions used. Efforts were made for the review of existing demand and supply forecasts to be as exhaustive as possible, although unintentional omissions may not have been avoided.

The presentation of the results is structured according to the successive methodological steps described above.

2. RESULTS: GLOBAL FORECASTS AND NATIONAL PLANS

2.1 Global forecasts

Global fisheries production reached 130.2 million tonnes in 2001, having doubled over the last thirty years (FAOSTAT, 2004). However, this expansion largely reflects the growth of aquaculture. While output from capture fisheries grew at annual average rate of 1.2 percent, output from aquaculture (excluding aquatic plants) grew at a rate of 9.1 percent. The latter is a faster rate not only than capture fisheries, but other animal food producing systems such as terrestrial farmed meat (FAO, 2003). Excluding aquatic plants, aquaculture output in 1970 accounted for 3.9 percent of total fisheries production, by 2001 that proportion had grown to 29 percent (FAOSTAT, 2004). By 2002, aquaculture output, excluding plants, reached 39.8 million tonnes compared with 2.6 million tonnes in 1970 (FishStat Plus, 2004).

Much of this aquaculture expansion has been due to China whose reported output growth far exceeded the global average. During the period 1980 to 2000, its 15.5 percent annual average growth rate of output was more than twice that of the rest of the world. Thus, from 28 percent of world aquaculture output in the 1980s, China’s share rose to half in 1990 and more than two-thirds by 2000. China’s exceptional expansion in absolute tonnage therefore distorts the global aquaculture scene. If it is excluded, world aquaculture output growth during the last twenty years was more moderate with declining rates of expansion (6.8 percent, 6.7 percent and 5.4 percent annual growth rates for the periods 1970–1980, 1980–1990 and 1990–2000 respectively) (FAO, 2003). The rate of expansion has also slowed down by decades, which is contrary to the scenario when China is included. This difference in growth rates is reflected in increases in annual output: with China, the 1990s saw an average annual increase of more than two million tons in global aquaculture output. Without China, the annual increase was less than half a million. To take account of China’s impact, and reported statistical concerns, Table 2 shows global production and average annual growth rates, both with and without China.

Table 2: Global aquaculture production (excluding aquatic plants)

	World			World excluding China		
	Output (tonnes)	Annual growth rate (percent)	Average annual absolute increase (tonnes)	Output (tonnes)	Annual growth rate (percent)	Average annual absolute increase (tonnes)
1970	2 555 591			1 783 115		
1980	4 764 481			3 433 025		
1990	13 044 063			6 574 354		
2000	35 611 656			11 138 103		
1970-80		6.4	220 889		6.8	164 991
1980-90		10.6	827 958		6.7	314 133
1990-2000		10.6	2 256 759		5.4	456 375
1970-2000		*9.2*	*1 178 536*		*6.3*	*311 833*

Data are three year averages centered on 1970, 1980, 1990 and 2000. Growth rates are compounded using three year averages as end points.
Source: calculated from FishStat Plus, 2004.

2.1.1 Future global aquaculture production

Forecasts of global demand for fishery products suggest that aquaculture output will have to continue increasing. Reduction fish accounts for approximately a third of output from the fisheries and capture fisheries provide more than 60 million tonnes of food fish, up from approximately 45 million tons in the early 1970s. However, most capture fisheries are at or near their limit of close to 100 million tons. Even if output were to continue to grow (at 0.7 percent annually), they will be incapable of meeting the projected demand for food fish.

Table 3: Projections of food fish demand (million tonnes)

Forecasts and forecast dates	Price assumption	By the forecast date		Calculated quantities required from aquaculture by the forecast date[4]				
				Growing fisheries		Stagnating fisheries		
		Global cons. per capita (kg/year)	Food fish demand (million tonnes) 4	Total output (million tonnes) 5	Growth rate (percent) 6	Total output [5] (million tonnes) 7	Growth rate (percent) 8	Average annual increase (million tonnes) 9
IFPRI (2020)	Real and relative prices are flexible							
Baseline		17.1	130	53.6[3]	1.8	68.6	3.5	1.7
Lowest[1]		14.2	108	41.2	0.4	46.6	1.4	0.6
Highest [2]		19.0	145	69.5[3]	3.2	83.6	4.6	2.4
Wijkström (2010)	Constant	17.8	121.1	51.1[3]	3.4	59.7	5.3	2.4
(2050)	Constant	30.4	270.9	177.9[3]	3.2	209.5	3.6	3.5
Ye (2030)	Constant	15.6	126.5	45.5[3]	0.6	65.1	2.0	1.0
	Constant	22.5	183.0	102.0[3]	3.5	121.6	4.2	2.9

[1] Assumes an "ecological collapse" of capture fisheries.
[2] Assumes technological advances in aquaculture.
[3] Assumes a growth of output of food fish from capture fisheries of 0.7 percent per year to the forecast date.
[4] From 2000; (35.6 million tonnes, three-year average of aquaculture output).
[5] Assumes zero growth in food fish from capture fisheries after 2001.
Sources: Calculated from Delgado *et al.*, 2003 (hereafter referred to as "IFPRI" – International Food Policy Research Institute); Wijkström, 2003; Ye, 1999.

Table 3 demonstrates this with three global forecasts for food fish demand. Two forecasts made by Wijkström (2003) and Ye (1999) assume constant fish prices. Their projections of the world fish consumption are based on demand variables (population growth and per capita consumption) and exclude real and relative prices. Global consumption of fish as food has doubled since 1973 (from 45 million tonnes to over 90 million tonnes) due to population growth and increases in per capita consumption (from 12 kg/year to 16 kg/year). One forecast by Ye assumes that even if per capita consumption of food fish remained at its 1995–1996 level of 15.6 kg per person, population growth would generate a demand for food fish (126.5 million tonnes) that would exceed the 99.4 million tonnes available in 2001.

Demand for food (and food fish) is primarily determined by four variables: demography, living standards, urbanization and price. World population growth rates have declined to 1.4 percent a year but regions such as sub-Saharan Africa continue to have high rates, with a possible population close to one billion by 2020. This population growth alone will increase demand, even if per capita consumption of fish were to remain at its low rate of 6.7 kg per year in the region. Countries such as China and India have slower population growth rates, but they have rising real per capita incomes. Income elasticity of demand for fish is higher in poorer countries, so income-induced demand, combined with urbanization, will increase demand for food fish there. Income and development variables appear to be the most important determinants of food fish demand, with population growth accounting for the remaining 40 percent (Ye, 1999).

Prices are an integral part of the International Food Policy Research Institute (IFPRI) model, which disaggregates food fish into two categories (high value and low value fish) according to their markets and price elasticities. On the supply side, the baseline forecast assumes that global output of food fish from capture fisheries will continue to grow at an annual rate of 0.7 percent. Prices can be estimated using an equilibrium model and these in turn will affect consumer demand and aquaculture supply. The baseline forecast predicts an increase in the real price of both high-value and low-value food fish by 2020 as well as an increase in its relative price (compared to substitutes). This increase has a dampening effect on demand in two ways. Firstly, given price elasticity of demand for fish (–0.8 to –1.5), the increase in real price will reduce the quantity demanded. Secondly, the increase in relative price, with positive cross-elasticity coefficients (at least for poultry), will produce substitution towards cheaper alternatives. This was corroborated by a recent FAO study, which compared scenarios of projected demand and supply based on constant and equilibrated relative prices and illustrated the dampening effect of a price rise on global demand for fish and fisheries products (FAO, 2004). This study found that with a price rise of 3 and 3.2 percent, world demand for fish (for both food and non-food uses) would result in a decline of 2.5 percent from expected quantities demanded in 2010, and 2.68 percent in 2015 respectively. Nonetheless, global per capita consumption of fish in IFPRI's baseline model is projected to continue rising (to 17.1 kg/year).

Per capita consumption of fish is critical to demand estimates. This is demonstrated by Ye's forecasts to 2030. For this time horizon, a 44 percent increase in per capita consumption would more than double total demand for food fish. Although fish has become more important in people's diet, reflected in the 15.3 percent contribution of fish in total animal protein in 2001, there is a potential for declining marginal utility and consumer saturation as incomes rise (Wijkström, 2003). This is apparent in Ye's model's results, which show that at constant prices, increases in per capita consumption are less than historic rates. Similarly, under the IFPRI baseline scenario where real prices of food fish are forecast to increase by 15 percent and prices relative to other animal substitutes by 20 percent, per capita fish consumption is forecast to grow at a slower rate to 2020 (0.4 percent) than over the 1985–1997 period (1.7 percent). Further, under the extreme scenario of a negative growth of production all capture fisheries commodities, including fishmeal and fish oil[4], the effect on reduction fisheries and prices (fish meal prices more than double and food fish prices increase by 35 to 70 percent) would be such that per capita consumption in 2020 would be lower than in 2001 (Table 3).

The rise in real price of fish however does provide an incentive for aquaculture, with its supply elasticity coefficient higher than that of capture fisheries. If higher prices spur technological innovations and needed investment, IFPRI suggests that aquaculture could expand faster than the baseline with a possible output of 69.5 million tonnes by 2020, representing an average annual growth rate of 3.2 percent.

To determine the implications of these three forecasts for aquaculture production, two scenarios are assumed. In the first, output of food fish from capture fisheries is assumed to increase at the same rate (0.7 percent) as the IFPRI baseline model until the forecast dates ("growing fisheries" scenario, Table 3). This increase is lower than historical rates but may still be optimistic (particularly past 2020). Under this assumption, food fish quantities derived from capture fisheries are deducted from the projected demand (column 4), and the residual is the amount required from aquaculture (column 5). As can be seen, all forecasts require a higher aquaculture output than the 2001 total of 37.9 million tonnes. If food fish from the capture fisheries does not increase at the rate projected, the demand gap to be filled by aquaculture will be higher than shown. This is illustrated in the second scenario labeled "stagnating fisheries" because it assumes that the production of food fish from capture fisheries does not increase beyond 2001. This is a plausible assumption given that capture production, excluding anchovies, has remained fairly stable since 1995 (Vannuccini, 2003) and is projected to stagnate (FAO, 2002). Consequently, increased excess demand must be met by aquaculture, and this increase is shown in column 7 (compared with column 5), with a corresponding higher growth rate from aquaculture (column 8). For example, in the Wijkström 2050 forecast, stagnation of landed quantities from the capture sector would leave an excess demand of 209.5 million tonnes, rather than 177.9 million tonnes in the case of the growing fisheries scenario, to be met by aquaculture. It should be noted however that columns 7 and 8 over-state the required output from aquaculture because the price effect, caused by the stagnation of capture fisheries after 2001, is not accounted for. Because of own-price and cross-price elasticities, this price increase would have a dampening effect on demand for food fish and column 4 would show lower figures.

When required growth rates in quantities required from aquaculture (column 8, Table 3) are compared with the historical growth rates in output (Table 2), the three forecasts seem plausible: given their assumptions, they indicate slower rates of expansion in aquaculture output than has occurred in the past. In Table 2, the highest required annual growth rate in aquaculture output (5.3 percent) is below the actual rates achieved since 1970, whether China is included or not. However, there are warning signs that the required expansion rates may not be achieved. Without China, the rate of expansion has been slowing to a growth rate not much higher than the Wijkström required rate (column 8, Table 3) and China itself is forecast to experience rates of growth far below those of the 1990s (Wang, 2001). In addition, environmental and social constraints to continued expansion will become more binding. This has already become apparent in Europe and North America where opposition to aquaculture has grown.

[4] This scenario was labelled as "ecological collapse" under the IFPRI projections. Although suggesting a dramatic decline and pessimistic outlook for capture fisheries, it is not, technically, a complete collapse.

The comparison of the three global forecasts and their implications for future supply requirements from aquaculture leads to nuanced conclusions with regard to their plausibility as much will depend upon the growth of Chinese aquaculture outputs. If China's rate of expansion continues at the rate of the 1990s, the required increases in quantities will be met, but maintaining such a rate may not be feasible (China's growth rate has been forecast to decline to 2 percent per year). Similarly, China is important when analyzing absolute tonnage (column 9). As Table 2 showed, average tonnage per year has been increasing for the last decades with or without China. Including it, absolute tonnage increased by more than a million tonnes per year on average over the period 1970–2000, and by more than two million tonnes a year over the period 1990–2000. Without it, tonnage increases have accelerated but were considerably smaller. If China's growth rate declines as anticipated, higher tonnage estimates will not be met. During 2001–2002 (the last years for which data are available), China's output increased by 6.6 percent, but global aquaculture production increased by just two million tonnes. This would suggest that most estimated requirements from aquaculture to meet demand projections (column 8) would not be met.

2.1.2 Regional perspectives

To determine whether countries can achieve global forecasts, aquaculture strategies, plans and related information from the major aquaculture producing regions was analyzed. In 2001, Asia produced more than 33 million tonnes of aquaculture products (excluding aquatic plants), representing 88.5 percent of world output. Moreover, its output since 1990 (using three-year averages), has been increasing at more than 11 percent per year, which is higher than the global growth rate shown in Table 2. Europe, in 2001, produced 3.4 percent of global output. Its largest producer is Norway, who has ambitious plans for expansion. However, the future of aquaculture production amongst members of the pre-2004 European Union is less promising as growth rates are projected to fall. Latin America and the Caribbean (LAC) have experienced a rapid expansion of its aquaculture output which grew at an annual rate of 15.5 percent during the 1990s. Total output remains small compared to Asia, representing only 2.9 percent of global aquaculture output (excluding aquatic plants) in 2001, although its share of global value was higher at 7 percent. Only four countries in Africa represent 92 percent of the continent's total aquaculture output: Egypt, Nigeria, Madagascar and Ghana. During the 1990's African aquaculture output expanded rapidly, and by 2000, it was about five times larger than a decade earlier. Yet, Africa's contribution to global aquaculture production remains small at 1.2 percent in 2001 (aquatic plants excluded), and the activity has not yet reached the momentum expected.

These regions are forecast to experience continued expansion, as shown in Table 4. According to the baseline and the highest IFPRI forecasts, Asia (excluding West Asia) will continue to produce the bulk of aquaculture output by 2020 (approximately 85 percent in both scenarios).

Table 4: Regional actual (2001) and forecasts of food fish from aquaculture for 2020

	Actual 2001		IFPRI Output Forecast for 2020[2]				Alternative Forecast	
			Baseline		Highest			
	Output (10^6 tonnes)	Share of global output (percent)	Output (10^6 tonnes)	Growth rate 2001-20[1] (percent)	Output (10^6 tonnes)	Growth rate 2001-20[1] (percent)	Output (10^6 tonnes)	Growth rate 2001-20[1] (percent)
China	26.1	68.8	35.1	1.6	44.3	2.8		
Europe[4]	1.3	3.4	1.9	2.0	2.3	3.0	1.5[5]	0.8
India	2.2	5.8	4.4	3.7	6.2	5.6	4.6[6], 3.3[7]	8.5[6], 8.2[7]
L. Am. / C.	1.1	2.9	1.5	1.6	2.1	3.5	24.8[3]	18
S. Asia (excl India)	0.7	1.8	1.2	2.9	1.7	4.8		
S-East Asia	2.9	7.7	5.1	3.0	7.3	5.0		
S-S Africa	0.06	0.1	0.1	4.6	0.2	8.1		
Global	37.8	100	53.6	1.9	69.5	3.3		

[1] Annual average growth rate 2001-2020; [2] IFPRI, 2003; [3] Wurmann, 2003; [4] The fifteen countries of the European Union in April 2004; [5] Failler, 2003; [6] by 2010, Gopakumar 2003; [7] by 2005, Gopakumar *et al.*, 1999.
Source: calculated from Failler, 2003, Gopakumar, 2003; Gopakumar *et al.*, 1999; IFPRI, 2003; Wurmann, 2003.

<u>Africa</u>

No quantified aquaculture production targets were available for African countries, Egypt being an exception – albeit not from a government source.

In the region, per capita consumption of food fish has stagnated at a low 8 kg a year over the last three decades and IFPRI's forecasts to 2020 suggest that only under the most favourable circumstances (i.e. rapid global aquaculture expansion) will it increase. This has clear implications for food security because of the importance of fish as a source of animal protein in some African countries (Ye, 1999). However, driven by a desire to maintain (if not increase) per capita fish consumption, a population that could increase by 50 percent to 1.2 billion by 2020 and accelerated urbanisation, demand for fish food is projected to more than double in both North Africa and sub-Sahara Africa by 2030 (Ye, 1999).

To meet this growing demand, many African countries are giving aquaculture a high priority on their development agendas. Egypt's output grew at an annual rate of 17.3 percent during 1990–2000 which is higher than the global average shown in Table 2. Recent growth has slowed down, but output in 2002 (376 296 tonnes) was still about 10 percent higher than in 2001. Aquaculture has been promoted as a source of food security and the goal is to increase per capita fish consumption to 14 kg per year by 2017 (El Gamal, 2002). It is also promoted for its contribution to the balance of payments. With its large trade deficit, Egypt perceives aquaculture as a means of import substitution and as a sector for generating exports income (El-Gayar, 2003) but the development of its exports of farmed sea bass and sea bream to Europe has been hampered by lack of conformity to hygiene requirements.

In this context, the sustainability of the rapid Egyptian expansion appears uncertain. Egypt's principal species is now tilapia, which accounts for almost half of the total output, but domestic prices have fallen (in nominal terms) because of large increases in supply. This has created a disincentive to producers. With water shortages, conflicts over resource use, and dwindling prices for bream, bass and tilapia, expected growth of output at historic rates appears over-ambitious.

In spite of Egypt's constraints, forecasts for aquaculture expansion in Africa generally are high, as shown for sub-Sahara Africa in Table 4. With its resource base of land and water, potential for expansion exists. Moreover, population growth and urbanization offer a strong domestic market in addition to the continent export potential. However, given its transport disadvantage, exports will focus either on high-value species or on value-added products. Some commercial farms have already successfully negotiated the transition from small-scale to market-oriented, large-scale production. In Zimbabwe, for example, one farm already exports tilapia fillets to Europe, generating approximately US$5 million a year. It not only generates foreign exchange, but employs more than 350 people and applies advanced technology for processing. South Africa's main aquaculture species (by value) is abalone which is exported to Asia for US$35 per kg. The first commercial harvest only began in 1998, but by 2003, output was 500 tonnes, with planned 800 tonnes in water for harvest by 2008. South Africa is so committed to aquaculture, and particularly mariculture, that it has developed an aquaculture park to expedite investment by foreign investors (Trade and Investment South Africa, 2002). Madagascar has attracted foreign investors for shrimp cultivation. Its annual aquaculture growth rate during 1992–2001 was 19 percent, a rate higher than the global average. Increases in shrimp output have more than offset declines in carp production. At the moment in third position in Africa in terms of aquaculture tonnage, Madagascar may surpass Nigeria (the continent's second largest producer) by 2010 if present growth rates are maintained.

However, as with Egypt, there are constraints to rapid expansion. Input costs are high, particularly feed costs, and the cost of credit still constrains the development of the activity. However, main constraints are linked to countries' instability and poor governance. If aquaculture is to expand at the forecast rate, it must be commercially-oriented, and thus requires environments conducive to investment. In addition, policy and political stability are of prime concern to African entrepreneurs (World Economic Forum, 2001). If the emphasis of NEPAD (New Economic Partnership for Africa's Development) on governance can mitigate some of the economic and political constraints, this should encourage capital investment (both domestic and foreign) into aquaculture in sub-Saharan Africa.

Asia

India, Bangladesh, Indonesia, the Philippines, Thailand and Viet Nam have quantified projections and these countries are amongst the top twelve producers in the world. Together, they accounted for 13.8 percent of world aquaculture output (excluding aquatic plants) in 2002 (Fishstat Plus, 2004). Comparing their forecasts with actual historical expansion allows us to gain insights into their aquaculture ambitions (Table 5).

Table 5: Historical and forecast aquaculture output in Asia (excluding aquatic plants)

	2000 output (tonnes)	Actual growth rates (percent)		Forecast growth rates (percent)
		1980–1990	1990–2000	
China	24 473 553	17.1	33.8	3.7 [2000–2010]
Bangladesh	654 745	7.9	12.8	4.1 [2001–2010]; 3.5 [2001-2020]
India	2 093 216	11.4	6.8	8.2 [2000–2005]; 8.5 [2001–2010]
Indonesia	800 682	9.9	5.1	11.1 [2003–2009]
Philippines	393 695	6.3	0.3	13.4 [2001–2004]
Thailand	716 651	10.2	9.0	1.8 [1996–2010]
Viet Nam	498 774	11.8	8.5	10.0 [2001–2010]

Data are three-year averages centered on 1980, 1990 and 2000. Annual growth rates are compounded using three-year averages as end points.
Sources: calculated from FishStat Plus, 2004. Forecast growth rates for Bangladesh, Indonesia, Philippines, Thailand and Viet Nam: national aquaculture development plans; for China: calculated from Wang, 2001; for India: Gopakumar, 2003 (period 2001–2010), Gopakumar *et al.*, 1999 (period 2000–2005 – for freshwater aquaculture).

China

Aquaculture output has been increasing rapidly, as shown in Table 2, and its share of total production reached 60 percent in 2000. By 2005, output is projected to reach 29.9 million tonnes representing 65 percent of the total Chinese fish production (Hishamunda and Subasinghe, 2003). Forecasts for 2010 are for total fishery production rather than aquaculture, but the former is projected to grow at a rate of 2.2 percent between 2000 and 2010 when total fisheries output will be 51 million tonnes (Wang, 2001). To estimate the contribution of aquaculture, its share in the total fish output was assumed to reach 70 percent by 2010, which would give an output of 35.5 million tonnes. This represents a 3.7 percent rate of growth from 2000 to 2010.

The IFPRI baseline model had projected a Chinese growth rate of 2.6 percent in food fish from aquaculture for the period 1997–2020. However, output since 1997 has grown more rapidly. Recent data showed a 6.6 percent increase in 2002 compared to 2001. Thus, meeting IFPRI's baseline growth rate target of 1.6 percent, or the higher target of 2.8 percent by 2020, appears within easy reach. However, although two-thirds of available paddy fields are under-utilized and yields from reservoirs and fish ponds could increase, constraints to the steady growth of the sector are anticipated (Wang, 2001). For example, concerns over the environment have curtailed expansion of intensive coastal aquaculture (Hishamunda and Subasinghe, 2003). Moreover, while aquaculture expansion in China has been actively promoted by the government as a means of providing food security, earning foreign exchange and generating employment, water shortages may constrain future growth (Hishamunda and Subasinghe, 2003). Consequently, to take into account potential growth constraints in the longer term simulation to 2020 and beyond, the growth rate has been reduced to an annual 2 percent.

India

As the world's second largest aquaculture producer, India is critical to regional and global forecasts. IFPRI forecasts (Table 4) suggest that its output could double by 2020. The higher forecast suggests an output almost three times that of 2001, with output increasing by an average of 200 000 tonnes a year. The growth rates required to meet these targets are lower than past rates shown in Table 5.

Two more optimistic forecasts, from the government-sponsored Indian Council of Agricultural Research and the Central Institute of Freshwater Aquaculture, are also shown in Table 5. According to their forecasts, production of farmed shrimp and fish, including from freshwater systems, could double by 2010 (Gopakumar, 2003; Gopakumar *et al.*, 1999) with both the expansion of areas under cultivation and increases in yields (respectively +50 and +45 percent for freshwater aquaculture). With limitations in the use of coast lines for intensive shrimp farming, only one fifth of the coastal area available for shrimp culture has been developed, and suitable areas, in particular in West Bengal remain available for exploitation. Inland saline water bodies also have the potential to support shrimp and Cichlids culture and increases in productivity are possible through the introduction of fish cage culture in reservoirs. Inland production (of carp) constitutes the bulk of Indian aquaculture and yields have increased tenfold with the application of modern technology. On the demand side, it is expected that higher incomes and urbanization are expected to increase per capita consumption, which, in conjunction with population growth, would create a domestic market to absorb increased supply. While the bulk of production is carp, catfish and freshwater prawn production are increasingly adopted as semi-intensive systems by farmers. Cultured freshwater pearls, along with non-conventional species such as ornamental fish, protein-rich algae and bio-fertilizers, are a new commodities contributing to the diversification of the sector and are potential high income earners.

The plan for freshwater aquaculture development carefully reviews the implications of achieving its targets in terms of necessary natural resources, fish seed and feed, finances, extension, post-harvest infrastructures and specificities (strengths and weaknesses) of each State, but, set against past production trends, forecasts appear unlikely to be realized. As Table 5 shows, despite absolute increases in output, growth rates over the last two decades have declined sharply. Moreover, during the 1990s, the annual average increase in output was under 100 000 tonnes, half the yearly amount needed to meet the higher IFPRI forecast to 2020. Recent data (FishStat Plus, 2004) confirm the slower growth: production figures for 2002 indicated an output that was barely higher than that of 1999, with an annual average increase in output under 20 000 tonnes for the period 1999–2001, whereas the meeting of the lower IFPRI forecast would require annual increases of approximately 116 000 tonnes.

<u>South Asia (excluding India)</u>

Bangladesh accounted for 94 percent of 2001 output from South Asia (India excluded). Its plan incorporates aquaculture within total fisheries production and forecasts aquaculture output mostly on supply factors (Department of Fisheries, 1999). Aquaculture expansion is projected to come almost equally from increased yields and from expanded area, and to account for almost half of total fisheries production by 2020. A notable feature of the Bangladesh plan is its evaluation of past plans and achievements. All previous seven five-year plans overestimated fisheries outputs, yet the gap has been narrowing. Within current fisheries projections (Table 5), aquaculture output is projected to continue growing, at a rate below historic rates which would nonetheless allow production to almost double by 2020. Recent data suggests that the target output will be met, if not surpassed: since the inception of the plan, output has grown at a rate approaching 10 percent. If Bangladesh meets its target of 1.3 million tonnes in 2020, it alone would have exceeded the baseline forecast for South Asia (excluding India) shown in Table 4.

<u>South East Asia</u>

Indonesia has an ambitious aquaculture development plan that forecasts a doubling of output over the period 2003–2009 (Ministry of Marine Affairs and Fisheries, 2003). Thus, total output is foreseen to reach 2.3 million tonnes in 2009. The sector is viewed as a source of economic growth and foreign exchange, with export earnings projected to increase nine-fold and reach almost seven billion dollars. In addition, per capita consumption of fish is projected to increase by almost a third to 32.3 kg per capita per year. The main source of expansion will be mariculture where, by 2009, almost half of the total output will originate from. Output from ponds and net cages is also projected to increase. However, the realism of these projections is questionable when compared to historical trends. Not only were export earnings from aquaculture in 2003 little changed since 1999, but the projected rate of expansion (11.1 percent) is much higher than earlier periods. 2002 data indicate that output grew only by 5.8 percent between 2001 and 2002.

The Philippines plan to produce 663 000 tonnes of farmed fish by 2004, which would require a much faster expansion rate than those experienced in the recent past. The plan recognizes the technical constraints the industry is facing (e.g. low productivity). It also states the need for an ecologically-friendly sector. However, output only reached 443 319 tonnes in 2002, which was a mere 2.0 percent increase over 2001 (although 12.5 percent more than 2000), compromising the likelihood of reaching the 2004 target.

The forecast by Thailand, on the other hand, appears to be an underestimate. The 1996 plan forecasted an output of 704 349 tonnes by 2010; this figure was surpassed in 2000. The main reason for the larger than expected expansion was shrimp output, Thailand's principal species, which grew by 30 percent during 1996–2000. Freshwater output in general also expanded sharply, with catfish production exceeding the 2010 forecast the same year. However, since 2000, shrimp output has declined, reflected by an 11 percent drop in output between 2000 and 2002. Notwithstanding, the actual annual growth rates for the period 1996–2002 remains at 2.6 percent, higher than the one forecasted (1.7 percent).

The Viet Nam Fisheries Plan recognizes aquaculture as a key sector to provide food security, earn foreign exchange and offer rapid financial rewards (Jacobsen, 2004). The potential for expansion exists with some 300 000 hectares of unexploited water and current low productivity. The Plan forecasts an output of 1.2 million tonnes by 2005 and 2 million by 2010. As Table 5 shows however, Viet Nam's growth rate of aquaculture output has been declining, and this forecast requires a higher rate of growth than occurred in the 1990s. More recent data indicate an even still slower rate of expansion: the period 2000–2002 saw minimal growth (FishStat Plus, 2004). Meeting its 2010 target would require a growth rate of 10 percent for the period 2002–2010 and this may not be easily achievable.

The four countries of South East Asia for which quantified plans were available are the major producers in this region, accounting for 89 percent of that region's total. Conclusions from these plans are mixed as Thailand appears likely to exceed its target, whereas the other three may not. The latter countries have ambitious targets requiring rates of growth that would reverse recent declining rates, which raises doubt over the probability of them reaching these targets. The Philippines and Viet Nam combined have experienced slow growth since 1999, and Thailand has actually experienced negative growth. The exception is Indonesia, although it is questionable whether its aquaculture sector will expand sufficiently to meet its targets. A projection of the four countries actual growth rates since 1999, weighted by their 2002 share of world output, would give an output of approximately six million tons for South-East Asia by 2020, a figure which nonetheless remains above IFPRI's baseline forecast (Table 4).

Europe

The IFPRI forecast for the 15 members of the European Union pre-2004 is for a growth rate approximating that of global output. This appears optimistic. As Tables 2 and 6 show, output from the European Union members grew historically at a rate below the global growth rate during both the 1980s and 1990s (even when China was excluded from global calculations). Moreover, recent data reinforce scepticism about the IFPRI forecast. All major producers among the 15, except salmon producers (Great Britain and Norway), have experienced actual declines in output.

The largest decline was in Denmark, which produced 23 percent less in 2002 than in 2001, although Spain and Italy had declines of more than 15 percent. The decline in France's output was small, but its 2002 total output was actually less than 1989. Norway, Great Britain and Ireland had positive growth in output, yet smaller than the global increase experienced in 2002 (5.3 percent) in the case of the latter two.

Table 6: Historical and Forecast Aquaculture Output in Europe (excluding aquatic plants).

	2000 output (tonnes)	Actual growth rates (percent)		Forecast 2000-2020[1]	
		1980–1990	1990–2000	Output (tonnes)	Growth rates (percent)
Spain	315 321	0.4	3.8	361 017	0.7
France	261 216	2.0	0.8	307 497	0.8
Italy	213 054	7.1	3.5	279 363	1.0
G. Britain	159 267	30.0	11.5	168 241	0.3
Europe-15	1 314 017	4.0	3.5	1 539 664	0.8
Norway	493 111	31.1	13.2	1 620 000[2]	6.3[2]
Europe	2 067 068	6.9	3.2		

Data are three year averages centered on 1980, 1990 and 2000. Annual growth rates are compounded using three year averages as end points.
[1]Failler, 2003; [2] The forecasts are exclusively salmon and trout, but include capture (Royal Norwegian Society of Sciences and Letters, 2003).
Source: calculated from FishStat Plus, 2004.

Two species (salmon and trout) account for approximately 80 percent of European aquaculture output (Failler, 2003). Norway is by far the largest producer of farmed Atlantic salmon both within Europe and globally, although Chile produces more Pacific salmon and trout. As Table 6 shows, Norway's output growth has been higher than the world average, even including China. Chile has managed to maintain its competitive position by research and technological advances, and the forecast in Table 8 assumes that it will continue. Norwegian figures shown in Table 6 are limited to salmonid production only and the country has ambitious plans to expand other species such as cod and mussel (The Royal Norwegian Society of Sciences and Letters, 2003). However, these plans recognize the environmental constraints linked to the uncontrolled growth of the sector.

While the IFPRI forecast for the 15 members of the European Union pre-2004 is unlikely to be realized, Norwegian forecasts appear plausible given historic growth rates. Norway is also committed to its aquaculture sector as a means of maintaining isolated communities. By 2020, even if the IFPRI projection were realized, Norway's output (of salmonids only) would exceed that of the 15 pre-2004 EU member countries.

The Latin America and Caribbean Region

Overall, the 36 countries of the Latin America and Caribbean (LAC) region have shown a remarkable dynamism, culturing more than 80 species and exhibiting an average annual growth rate in output well above the global increase. The region's share of global aquaculture value rose to 7.1 percent in 2001, worth almost four billion dollars, reflecting that the species cultivated in LAC tend to be high value. In fact, the unit value of output from the LAC (particularly from Central America) is among the highest in the world. The two dominant aquaculture producers in LAC are Chile and Brazil. Together they account for 70 percent of aquaculture output (excluding aquatic plants) in the region. Both have ambitious fisheries development plans, although in the case of Brazil not specific to aquaculture. The rapid expansion of aquaculture output in both countries is shown in Table 7.

Table 7: Aquaculture output (excluding aquatic plants) in tonnes in LAC 1989–2002

	1989	1991	1993	1995	1997	1999	2001	2002
Brazil	18 170	23 390	30 390	46 202	87 674	140 657	207 510	246 183
Chile	15 360	47 579	86 442	157 083	272 346	274 216	566 096	545 655
Ecuador	71 211	107 145	87 763	105 597	134 497	126 575	67 169	70 181
Sub-total	**104 741**	**178 114**	**204 595**	**308 882**	**494 517**	**541 448**	**840 775**	**862 019**
Total LAC	**155 401**	**248 729**	**305 151**	**440 284**	**670 167**	**738 747**	**1 084 432**	**1 122 696**

Source: FAO FishStat Plus, 2004. LAC countries are listed in Appendix 2.

LAC appears to be the region with the highest aquaculture potential, because of its favourable climate, freshwater resources and available coastline. Brazil alone has 8 500 km of coastline and 12 percent of the world's freshwater reserves. It has the largest mangrove forests in the world, and even without depleting them, has abandoned salt flats available for shrimp farming. The abandoned flats are ten times larger than the area currently under shrimp cultivation (Nunes and Suresh, 2001). With this identified potential, Brazil in its plan claims to be "the last great frontier of aquaculture in the world" (Secretaria Especial de Aquicultura e Pesca, 2003, p. 9).

Regarding markets, some countries such as Brazil and Mexico have the population base, income growth and urbanisation necessary to support a viable domestic market; others such as Costa Rica and Honduras can take advantage of their proximity to the US and the presence of favourable trading agreements, to export to North America. Even distance to markets can be overcome if high transport costs are offset by low production costs. Chile, because of lower production costs, is able to compete successfully against North American farmers in the US market for fresh Atlantic salmon.

In addition to natural resources and access to markets, aquaculture potential is enhanced by governments' commitment to the sector. Not only can aquaculture generate employment and incomes, it also generates foreign exchange, and this has been the strongest motivator behind government support (Hernández-Rodríguez *et al*, 2001). Governments in Central America have specifically targeted exports of non-traditional products (such as shrimp) for selective promotional incentives (Stanley, 2003). In addition to generating foreign exchange from exports, aquaculture offers the means to save foreign exchange by import substitution. Brazil's intention to expand its production of tilapia is prompted by saving the foreign exchange cost of fish imported from Argentina and Uruguay (Ministerio da Agricultura e do Abastecimento, 2000).

Foreign exchange will continue to be a motivation behind the expansion of aquaculture in LAC, which has the potential to become an even more significant producer in the future. Table 4 showed IFPRI's forecast for the region. It anticipated continued expansion for LAC but at a much slower pace. The baseline scenario foresees a growth rate lower than the global average. Even the highest forecast suggests that by 2020 LAC's output will fail to double. This appears to be an underestimation of LAC's aquaculture potential. As Table 7 shows, output more than quadrupled over the last decade.

An examination of the contents of the plans for the two principal producers in LAC further suggests that the IFPRI forecasts are underestimates. Given their commitment to the sector, governments in both countries have ambitious plans for continued growth. Brazil is planning to increase its fisheries output by 50 percent by 2006 (Secretaria Especial de Aquicultura e Pesca, 2003). With a declining trend in its capture fisheries since the 1980s, this increase must come mostly from aquaculture. Tilapia production alone is projected to increase tenfold (to 420 000 tonnes by 2010) (Ministerio da Agricultura e do Abastecimento, 2000). Chile, in addition to developing new species for aquaculture, is planning to double its salmonid production between 2002 and 2013, in line with its estimates that global output of farmed salmon will double (to 2.5 million tonnes) by that date (Subsecretaria de Pesca, 2003).

This is however a conservative forecast in comparison to Wurmann's (2003) projection that aquaculture output from LAC could increase from its 2001 output of 1.1 million tonnes to 5.2 million in 2010 and 24.8 million tonnes in 2020. This latter quantity would equal two-thirds of the 2001 world aquaculture output, and is more than ten times IFPRI's highest projection for the region in 2020. The 18 percent average annual growth rate required to achieve this level of output is significantly higher than the 14.9 percent average annual growth experienced over the 1990–2000 decade. Yet, while high, the predicted output appears feasible. Brazil and Chile each had aquaculture output growth rates that exceeded 18 percent between 1990–2000, with annual average rates of 24 and 29 percent respectively (Table 8).

Table 8: Historical and forecast aquaculture output (excluding aquatic plants) in Chile and Brazil

	2000 output (tonnes)	Actual growth rates (percent)		Forecast growth rates (percent)
		1980–1990	1990–2000	
Brazil	175 729	18.7	23.9	22 [2001–2006][1]
Chile	410 633	48.0	29.2	5.9 [2003–2013][2]

Data are three year averages centered on 1980, 1990 and 2000. Annual growth rates are compounded using three year averages as end points.
[1] Estimated from the contents of Brazilian documents anticipating a decline in growth rates over 2003–2006, yet a 25.3 percent annual increase in tilapia production over the period 2003–2010.
[2] Concerns salmonid production only.
Source: calculated from FishStat Plus, 2004 and national aquaculture development plans.

<u>The two dominant species: carp and salmon</u>

Fish is an important source of animal protein in Asia and parts of Africa; it also contains the micronutrients critical for women and children. Because of this, affordable fish such as carp, which is the principal cultivated species globally, is critical to food security. In 2002, carp production represented 43 percent of the world aquaculture tonnage (aquatic plants excluded), with Asia, and in particular China, being its main producer (78 percent) (FishStat Plus, 2004).

On the supply side, carp production is expected to continue its expansion as Egypt, India and Bangladesh have explicitly indicated their intention to increase their output through intensification of pond culture, and China suggested it through its support to rice-fish farming. On the demand side, this species was classified in the "low value fish" category by IFPRI, with the developing world its main consumer. With most of the Cyprinid production consumed domestically, and an anticipated slow down in the consumption of low-value fish products as a consequence of diversification in diets and increased purchasing power, new markets will have to be found in locations where either consumer tastes are acquired and/or capacity to pay exists (Delgado *et al*., 2003). Carp, however, was not considered by China and India as a strategic species for export in this country, despite foreseen increases in demand in South Asia and sub-Saharan Africa, in particular in the latter where it is unlikely to be met by increases in production (Delgado *et al*., 2003; Hishamunda and Subasinghe, 2003). European tastes are not used to carp – this trend is not expected to change with a 0.1 percent growth in consumption in low-value fishes to 2020 indicated by IFPRI, whereas Chinese and Indian cuisines can accommodate well the bony structure of the species (SCP, 2002). In India, although annual fish expenditure was lowest amongst the poor and the very poor, most of the amount spent went on Catla and Rohu, indicating that increased production and improved access to fish, in particular carps, would benefit the poor (Bhatta, 2001). This contrasts with Bangladesh where Indian Major Carps (Rohu, Catla and Mrigal) fetched higher prices and consequently, were bought by higher income groups (Alam, 2002), revealing that market situations are not uniform across, even within, regions. Future demand for carps is thus likely to be constrained to specific geographical areas, mainly in developing countries, where affordability is key to maintaining or developing market segments, but may not satisfy foreign exchange earnings. By contrast, the versatility of tilapia may prove more useful in targeting developed country markets.

A threat to the forecasted expansion plans of LAC is the future profitability of salmon farming. In 2001, salmonids were the principal species cultivated in LAC, accounting for almost half the region's tonnage and value. This was due almost exclusively to Chile. The Chilean plan assumes nominal prices of salmon of US$3–4 a kilo, somewhat higher than 2001 prices. However, Norway (and Canada) also plan to expand salmon production. The most conservative Norwegian forecasts anticipate a doubling of Norwegian salmonid output by 2020, but the majority foresee an increase considerably higher. This will put pressure on prices. The Chilean plan does recognize the need for new markets, with a particular interest in China and Brazil, where increasing incomes and urbanisation are creating a new demand for high-value species. However, it is questionable whether increases in demand will be sufficient to maintain prices. Average costs have fallen appreciably due to selective breeding but the most rapid gains may have already been made. This could put pressure on profit margins (Aerni, 2001) and in turn affect incentives to continue investing in the industry.

<u>Conclusion</u>

Compared national ambitions, independent projections for China and Latin America appear low, whereas those for South East Asia and Europe of the 15 members pre-2004 appear overestimations. China is clearly critical to regional (and global) production: whilst historic growth rates cannot be maintained, an estimated annual output growth of at least 2 percent until 2020 is plausible. Similarly, aquaculture plans for the two principal producers in Latin America, Brazil and Chile, suggest that IFPRI's projections are underestimates. Governments in both countries plan to promote the sector and, as has been demonstrated in China, this is a key factor in successful aquaculture expansion (Hishamunda and Subasinghe, 2003).

Expansion by China and Latin America would be sufficient to offset the slower than anticipated expansion in South East Asia and European Union countries.

2.2 National projections

An indication of the contents and realism of national projections was given in the previous section. A summary of the contents of national plans used in the analysis (quantified targets, assumptions and requirements, and principal threats or difficulties to overcome) is presented in Appendix 1. The full list of documents used is provided in Appendix 2.

2.2.1 The "sum" of national production targets the plans – comparison between global and national forecasts

Based on the information extracted from national documents on foreseen annual growth rates and production targets for the sector, individual country projections were "standardized" for the years 2010, 2020 and 2030 to sum up projected quantities for these years. Calculations are provided in Table 9. When available, details of production forecasts by system or species are provided.

Based on the eleven country plan projections, Table 9 indicates that the average annual growth rates for the aquaculture sector will be, for the period 2010–2030 (adjusted figure for 2030):

- with China's growth assumed at 3.5 percent *per annum*: 4.8 percent.
- with China's growth assumed at 2 percent *per annum*: 4.5 percent.

Recalculated for the period 2002-2015 (using FAO production figures for 2002 and applying each country's forecasted growth rate to the year 2015), average annual growth rates obtained are:

- with China's growth assumed at 3.5 percent *per annum*: 5 percent.
- with China's growth assumed at 2 percent *per annum*: 4.1 percent.

The above two figures averaging 4.55 percent, this rate is consistent with the figure of 4.5 percent for the sector's growth advanced by FAO (2004).

A second step was to compare the sum of national production targets with projected requirements from aquaculture in 2010, 2020 and 2030, which were given in Table 3.
Two scenarios were envisaged:

1. Assuming that output world from capture fisheries continues to grow at an annual rate of 0.7 percent per year (IFPRI's assumption) – Figures from column 5, Table 3 (IFPRI and Ye's high estimates). This scenario was labelled as "*optimistic*".
2. Assuming a zero growth from capture fisheries from year 2001 onwards – Figures from column 7, Table 3 (IFPRI and Ye's high estimates), which can be considered as a baseline or "*stagnating fisheries*" scenario.

In each case, two growth rates were envisaged for China (3.5 percent and 2 percent *per annum*). In addition, a first projection was done with annual average growth rates assumed constant to the year 2030. In a second calculation, national growth rates were reduced by 40 percent to calculate output for the period 2020–2030, to reflect the likelihood of pursued global output growth, yet at declining rates (see footnote [2] in Table 9).

Table 9: Individual aquaculture projection forecasts from country plans and readjusted to 2010, 2020 and 2030

	Production forecasts ('000 tonnes)			**Production outlook with constant forecasted national growth rates ('000 tonnes)**			**Production outlook with adjusted forecasted national growth rates over the period 2020–2030 ('000 tonnes)** [1]
	Start year of plan and production	End year of plan and production	Forecasted annual growth rate (percent)	**2010**	**2020**	**2030**	**2030 adjusted**[2]
Bangladesh	2001	2020					
Total	*691*	*1 340*	3.5	946	1 340	1 899	1 543
India (freshwater)	1995	2005					
Total	*1 512*	*3 313*	8.2	4 904	10 744	23 540	14 813
China	2002	2010					
1. annual growth rate = 3.5 percent	*29 100*	*37 023*	3.5[3]	37 023	52 225	73 669	60 015
2. annual growth rate = 2 percent	*29 100*	*33 427*	2.0	33 427	40 747	49 670	44 127
Indonesia	2003	2009					
Total	*1 220*	*2 300*	11.1	2 556	7 355	21 160	11 376
Philippines	2001	2004					
Total	*435*	*663*	15.1	1 542	6 299	25 723	11 326
Thailand	1996	2010					
Freshwater	*229*	*230*	2.0				
Coastal	*324*	*404*	1.6				
Total	*553*	*704*	1.7	704	838	996	914
Viet Nam	2001	2010					
Total	*850*	*2 000*	10.0	2 000	5 175	13 392	7 653
Brazil	2003	2010					
Tilapia	*86*	*420*	25.3				
	2001	2006					
Total	*210*	*641*	22[4]	1 257	9 185	67 089	21 347
Chile	2003	2013					
Salmonids	*450*	*900*	5.9	757	1 348	2 403	1 706
Canada	2000	2015					
Salmon	*85*	*350*	9.9				
Cod	*0*	*128*	247.1				
Total	*113*	*577*	11.5	335	994	2 946	1 557
Egypt	2000	2017					
Total	*340*	*840*	5.5	579	985	1 677	1 223
				2010	**2020**	**2030**	**2030 adjusted**[2]
	Total, with China annual growth = 3.5 percent			52 604	96 487	234 494	133 473
	Total, with China annual growth = 2 percent			49 007	85 009	210 495	117 585

[1] Using initial year of plan as baseline. [2] Reduced by 40 percent. [3] Calculated on the assumption that aquaculture production would represent 75 percent of total fish production. [4] Estimated from the contents of Brazilian development plan. 2006 figure was calculated using this growth rate.
Source: national aquaculture development plans.

Table 10: Comparison of the sum of national aquaculture production forecasts with quantities required from aquaculture to fulfil demand for fish (Table 3) in 2010, 2020 and 2030. Quantities are expressed in '000 tonnes

1. Optimistic scenario (capture fisheries annual growth rate = 0.7 percent)				
Simulation 1: using China annual growth rate = 3.5 percent				
	2010	2020	2030	2030 adjusted [2]
Sum of national aquaculture production forecasts [1]	52 604	96 487	234 494	133 457
Quantities required from aquaculture	51 100	69 500	102 000	102 000
Percentage fulfilled by national forecasts	103	139	230	131
Simulation 2: using China annual growth rate = 2 percent				
	2010	2020	2030	2030 adjusted [2]
Sum of national aquaculture production forecasts [1]	49 007	85 009	210 495	117 569
Quantities required from aquaculture	51 100	69 500	201 000	102 000
Percentage fulfilled by national forecasts	96	122	206	115
2. Stagnating fisheries scenario (capture fisheries annual growth rate = 0 percent from 2001)				
Simulation 1: using China annual growth rate = 3.5 percent				
	2010	2020	2030	2030 adjusted [2]
Sum of national aquaculture production forecasts [1]	52 604	96 487	234 494	133 457
Quantities required from aquaculture	59 700	83 600	121 600	121 600
Percentage fulfilled by national forecasts	88	115	193	110
Simulation 2: using China annual growth rate = 2 percent				
	2010	2020	2030	2030 adjusted [2]
Sum of national aquaculture production forecasts [1]	49 007	85 009	210 495	117 569
Quantities required from aquaculture	59 700	83 600	121 600	121 600
Percentage fulfilled by national forecasts	82	102	173	97

[1] Projected aquaculture quantities for the years 2010, 2020 and 2030 are the *sum* of national projections, obtained for each country studied by applying their forecast annual growth rates linearly to their current aquaculture output to the year 2030[5].
[2] 2030 adjusted: national annual growth rates (taken from individual country plans) were reduced by 40 percent over the period 2020–2030 to account for declining growth rates over time.
Source: calculated from national documents and Table 3.

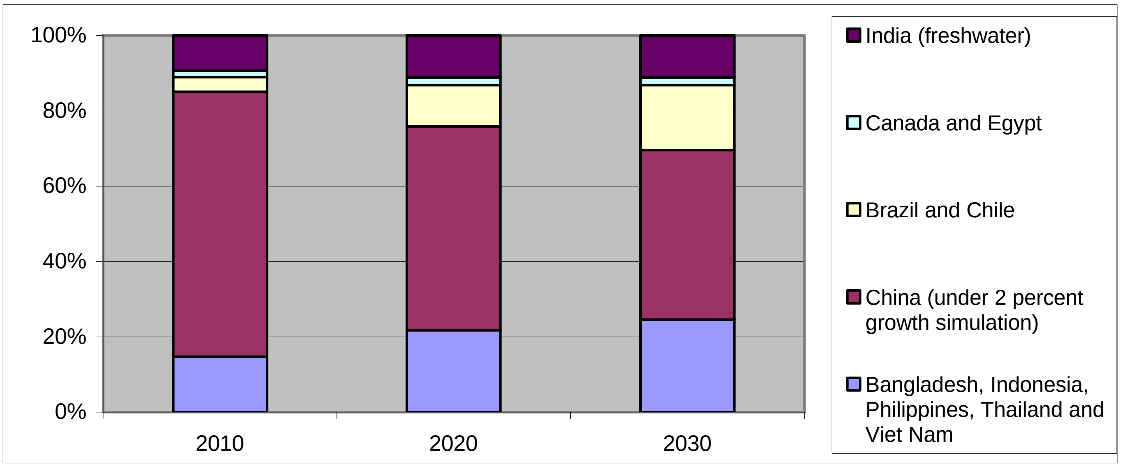
Table 10 presents the results obtained. Overall, they indicate that, based upon the assumptions made and the country data available, there should be no shortage of fish in the two forthcoming decades.

Under both the "optimistic" and "stagnating fisheries" scenarios, and with China maintaining a growth rate of 3.5 percent, the projected aquaculture production from the countries studied would largely meet the quantities required by the sector (139 and 115 percent respectively) in 2020. Although only 88 percent of the requirements would be met in 2010 under the "stagnating fisheries" scenario, this figure accounts for only eleven countries production. It is expected however that upcoming producers, for whom projections were not yet available, would contribute to the filling of this gap. However, under the same scenario, and in the case of Chinese aquaculture experiencing a slower growth rate, food fish requirements from aquaculture would only be met at 82 percent. Using the adjusted – and more realistic – annual growth rates for the period 2020 to 2030, aquaculture may just provide the quantities of fish required in 2030, in particular under Simulation 2 (97 percent of the requirements met). This highlights the continued dependence on China to supply the bulk of production. However, if

[5] Forecasted annual growth rates (calculated on the basis of production target figures provided in national aquaculture development plans or expert opinion in the case of China and Egypt) were: Chile: 5.9 percent, Indonesia: 11.1 percent, Philippines: 15.1 percent, China: 3.5 percent and 2 percent, India (freshwater): 8.2 percent, Egypt: 5.5 percent, Brazil: 22 percent, Canada: 11.5 percent, Viet Nam: 10 percent, Bangladesh: 3.5 percent and Thailand: 1.7 percent.

Brazil and Chile achieve their aquaculture production plans, they will increasingly weigh on the world aquaculture scene, in particular if the growth of their "younger" aquaculture sectors declines in the long term at a slower rate than in other regions, e.g. China and other Asian countries where the industry will have, by then, reached its maturity (Figure 1).

Figure 1: Contribution of countries studied to aquaculture output forecasted in 2010, 2020 and 2030, based on national aquaculture development plans (with adjusted growth rates for the period 2020–2030



2.2.2 Constraints to growth

Despite these encouraging results, it is wise to remain cautious as there may be limits to the expected growth of the sector. On the demand side, worldwide compliance with HACCP (Hazard Analysis Critical Control Point) standards and traceability regulations is going to be crucial to reduce potential aquaculture hazards (e.g. common post-harvest hazards, environmental contamination, contamination of fish feeds, misuse of veterinary drugs, occurrence of parasites) and enhance product quality and consumer confidence (Josupeit and Franz, 2004). Post-harvest losses are also to be curbed in the interest of optimization of output use and food security (Hongskul, 1999). On the production side, constraints to overcome are simultaneously technical and social in nature.

Disease

Disease is one of the most significant constraints to aquaculture production and trade and has increased the vulnerability of the shrimp sub-sector in particular (de Silva, 2001). In the 1990s, disease threatened shrimp production in Ecuador, which, by 2001 as Table 4 showed, had only half the output of the mid 1990s. Although many microbial and viral infections are not considered to be a direct threat to human health, they negatively impact upon product marketability and consumer confidence (Subasinghe, Bontad-Reantaso and McGladdery, 2001). The translocation of pathogens through the increase in movement and trade in live aquatic species and aquatic products triggered by the internationalisation of markets has accelerated the spread of diseases (*ibid*.). The implementation of international codes of practice and their strict protocols necessary to minimise risks of disease transmission, may, in the short-term, have slow-down effects on global production and push prices up.

Social opposition

Social problems and opposition to the aquaculture have already been experienced in the case of salmon producing countries such as Chile where salmon farming created some social dislocation and marginalization of the poor which, in turn, led to resistance to salmon farming and even deliberate destruction of cages (Barrett, Caniggia and Read, 2002). In Canada, salmon fish farms have been increasingly seen as a threat to the Aboriginal Right to fish and Indigenous People's groups have been lobbying the Canadian government to oppose the development of any new fish farm and maintain its moratorium on ocean net cage farming (Union of B.C. Indian Chiefs, 2004; Georgia Strait Alliance, 2002). Cases of opposition to shrimp farming have been well publicised around the world, mainly due to its attributed impacts on mangrove destruction. In India, opposition to the activity culminated in December 1996 with the Supreme Court decision to ban shrimp culture within Coastal Regulation Zones (Aquaculture Authority, 2002). Ethical questions over the large differential between the very low wages received by farmers and the price of the commodity on international markets were raised in the case of red seaweed farming in Tanzania (Bryceson, 2002).

Macro-economic context, political instability and administrative burdens
Handicaps to continued, even accelerated, expansion may include macro-economic variables affecting predominantly developing countries such inflation and exchange rate instability impacting on fish prices and international trade, as well as to policy and regulatory uncertainties (Wurmann, 2003 with reference to LAC). Political stability and continuous commitment to the development of aquaculture will be crucial to maintain the momentum gained by some producing countries and trigger initiatives amongst up-coming producers. Finally, modifying legal and regulatory frameworks to alleviate procedural and administrative constraints and define access regimes, whilst emphasizing good management practices, will be another challenge to overcome in order to stimulate the development of the sector (Gilbert, 2002; Sandoval, 2002, e.g. of Chile).

Fishmeal availability
This issue remains much debated. Concerns over shortages in fish feed, or the "fishmeal trap" (Wijkström and New, 1989), are not new, but have been increasingly reported as one of the main future warning to the sustained growth of the sector (e.g. Naylor *et al*., 2000,) and have contributed to the bad press received by aquaculture industry (e.g. *The Guardian*, 18 February 2003; Tuominen and Esmark, 2003). In 2000, it was estimated that aquaculture was the highest consumer of the world fishmeal (35 percent), compared to 29 percent for pigs, 24 percent for poultry and 12 percent other uses, mainly the pet industry (FAO, 2004). Fluctuations in the catch of the Peruvian anchovy, which is the main component of fishmeal, have led to periodic price increases, although the switch to soymeal and other vegetable-based feeds by the poultry and pig industries buffered the variations (FAO, 2004). However, the stability of the price ratio between soymeal and fishmeal should not be taken for granted as exemplified during the last El Nino event which led to the soaring of fishmeal prices in comparison to those of soya (*ibid*.). Given the price inelasticity of fish meal (Crowder, 1990) and the current lack of suitable substitutes to fish protein and oils, the forecasted, yet gradual, increase in the real price of fish feed will be a challenge to all shrimp and salmon farmers (New and Wijkström, 2002) in the future, if they expand output as planned.

Yet, only 37 percent of the total aquaculture production in 2001 was fed on formulated fishmeal (A. Tacon, personal communication). Although this share is likely to increase with intensified aquaculture production and reliance on commercial aquafeeds to enhance the growth of reared carp, tilapia and catfish (New and Wijkström, 2002), on-going research shows that progress has been made in the finding of substitutes with similar properties as marine oil in the diets for carnivorous species (Opsahl-Ferstad *et al*., 2003 with the example of genetic modifications of rapeseed to become suitable as fish feed; Hardy, 2000, regarding the use of enzymes supplements to increase the nutritional value of alternate (vegetable-based) feed ingredients), in an attempt to turn fish “vegetarian” (Powell, 2003). These developments could complement the use of discards from the marine capture fishery to maintain the supply of fish feed to the farming activity (New and Csavas, 1995).

3. PLANNING LESSONS

A great disparity was encountered amongst the plans. This was not so much due to projections *per se*, but rather to the thoroughness and depth in which each country went to prepare its production forecasts.

Although dating back from the 1980’s, a number of FAO publications and guidelines on aquaculture planning have been produced in the context of aquaculture development. It is not the intent of this section to “reinvent” them as they remain valid today, but to provide a different perspective on the process of planning and forecasting aquaculture development. Given the increasing stress put on aquaculture to be the new supplier of fish, and thus, if one adopts this position, the obligation of countries to achieve the production targets set in their plans, it is useful to ask:

What makes a successful planning process?
What assumptions and factors upon which to base projections should be taken into account?
What decision-making methods are most suitable, and in which context?

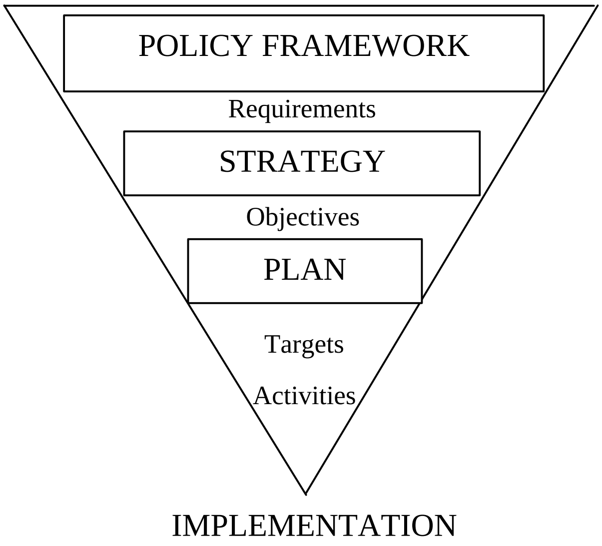
To attempt to answer these questions, a brief overview of the logical steps of planning is presented, followed by a section reviewing planning methodologies available to planners. Based on these considerations and on the methodologies identified in country plans, some thought is given on the requirements for sound and thorough aquaculture planning.

3.1 Planning: a rational process

Documents setting out clearly the logic of planning are scarce, even in the wider context of agricultural development. Publications on planning methods, however, are available but they provide little insight into the *rational process* involved in the planning of the development of a sector like aquaculture.
It may be easier to visualise the rational planning process in the form of an inversed pyramid (Figure 2).

The *policy framework* spells out the broad directions of development a country wishes to follow, for a given sector (aquaculture for example). Each direction of development contains one or more aims, or necessary requirements for a country to develop its aquaculture sector. By their very nature, these requirements are qualitative and broad in scope. Defining a framework of development is thus the first step of the planning process. Designing a *strategy* comes second, as a strategy takes each requirement of the framework further by envisaging how each could be met. The concretization of a requirement will require the setting of objectives. How to go about achieving these objectives will be provided in the *plan* (the third step), which should specify the quantitative targets related to the objectives enumerated in the strategy, as well as the activities to implement to achieve the targets.

Figure 2: Rational planning process



In relation to aquaculture development, each step of the process is however rarely encountered, as it depends largely on the advancement of the sector in a given country. Countries wishing to develop their yet marginal aquaculture sector may only possess a framework, whilst those at a more advanced stage will have formulated strategies and plans to guide and manage aquaculture development at the national level. The country documents obtained ranged from frameworks to plans, with production targets and corresponding activities. Their close examination however revealed a great deal of confusion over appropriate use of planning terms and development logic.

3.2 Planning methods

3.2.1 Types of planning

Planning processes have been distinguished based on the form, degree of public (government) and private (enterprises) participation and nature of policies. Hence the existence of directive, indicative, incentive and strategic planning (Hamlisch, 1988; Breuil, 1999) which relied on a steering committee, usually composed on national planners, with, if necessary, representatives from development agencies, international experts and members of the public and private sectors, which, in turn, appointed a "working party" with multiple skills to draft a strategy and a plan of development (Maine and Nash, 1987). Based along the same lines, but recognising the importance to give a voice to those affected by the development of a sector, recent planning methods have placed a stronger emphasis on the participation of both stakeholders and the public, often at the strategy level, by privileging a more consultative and participatory approach. Drawn from the three types of planning methods given by Hamlisch (1988) and with emphasis on participatory processes, Sevaly (2001: 83) describes today's three main categories of stakeholder involvement as instructive (when "the government makes decision but mechanisms exist for information exchange"), consultative (when "the government is the decision-maker but stakeholders have a degree of influence over the process and outcomes"), and cooperative (when "primary stakeholders act as partners with the government in the decision-making processes").

3.2.2 Participation and consensus

Benefits of public participation in natural resources planning and management are now well established and the literature contains a wealth of examples from this field. However, despite its advantages, public participation, in the form of consultation forums, public comment processes and opinion polls, has shown its limitations when it fails to quantify trade-offs and consequently results in conflicts (Ananda and Herath, 2003). In addition, barriers to successful planning have been identified as the lack of agreement on goals, the rigidity of the design process, the procedural requirements and the lack of trust, all being due to institutional defaults (Lachapelle, McCool and Patterson, 2003). To overcome problems inherent to the nature of participation, a number of methods to rationalize decision-making and ensure its transparency and legitimacy (Mascarenhas and Scarce, 2004), have been developed and documented, often with reference to forest and water resources management –the fisheries sector notably missing from the literature on the subject. A range of Multi-Criteria Decision-Making (MCDM) procedures, including Analytic Hierarchy Process (AHP), Expected Utility Method (EUM), Compromise Programming (CP) have been used successfully to rank, according to their importance, interest groups, issues studied and alternative plans after public opinions and preferences were elicited (Pavlikakis and Tsihrintziz, 2003). The incorporation of preferences in decision-making processes through the modelling of stakeholder values was also shown to be a suitable process to quantify trade-offs and thus minimise conflict by making the right choices (Ananda and Herath, 2003). This complements structured decision-focused approaches which can be used to specify and organise values, in turn using these to create alternatives and assess trade-offs to achieve a balance between key objectives (Gregory and Keeney, 2002). Finally, scenario planning, which consists of contrasting a few scenarios to explore the uncertainty surrounding the future consequences of a decision, has proved useful in the field of conservation biology (Peterson, Cumming and Carpenter, 2003). Underlying all methods is, of course, the need for putting a group of people together, whose interests and concerns are representative of those at stake.

One aspect these approaches tend to overlook, however, is consensus-building not only for management of a resource, but also its future development, understood here in terms of utilisation and enhancement. One method appears to stand out to reach consensus on how this could be envisaged: the Delphi method. This method, applicable to any professional field, is a simple and “flexible” group facilitation technique, based on an “interactive multistage process, designed to transform opinion into group consensus” (Hasson, Keeney and McKenna, 2000). In the context of natural resources management, it allows multiple requirements to be given equal weights and expert opinion to be voiced on any natural resource issue whilst moving towards greater agreement (Taylor and Ryder, 2003). In the context of foresight studies, it has been used as a tool forecasting development (e.g. investigation of market niches with potential for Austrian dominance in the next 15 years) whilst enabling the coordination of expectations and decentralised actions (Tichy, 2001). This latter case closely matches what the planning of aquaculture development requires.

3.3 Reflections on aquaculture country plans and strategies

3.3.1 What are the criteria for a successful planning process?

The above review has highlighted some criteria which could be useful in assessing the contents of national aquaculture plans and strategies. They are listed in Table 11, with the number of times they appeared to have been taken into account during the formulation of national plans and strategies indicated opposite.

Table 11: Criteria for a successful planning process with corresponding number of times encountered in country plans[1]

Criteria 1: *legitimacy*. Involves three sub-criteria:	
1. fair representation: government, industry representatives, academics, general public, interest groups, international organisations.	1
2. appropriate government resources, reflecting government commitment.	1
3. consensus-driven process (Mascarenhas and Scarce, 2004).	1
Criteria 2 – *transparency* over methods used to achieve goals.	1
Criteria 3 – *agreement* on (Lachapelle, McCool and Patterson, 2003):	
1. goals set	1
2. flexibility of method used	1
3. clarity of procedure used	1
4. trust amongst participants	0
5. examination of alternatives	0

[1] The figures corresponding to each criterion are subjective and as such, they should be viewed only as indicative of the weight given to the criteria in individual country plans.

3.3.2 What should be the assumptions and factors upon which to base projections?

Complementing the above, a number of relevant and country-specific factors upon which to base projections have been extracted from the analysis of individual country plans and strategies. Some of the generic factors used by individual countries to establish a diagnosis of the status of their activity as well as devise future plans and define targets have already mentioned in section 2, under Regional Forecasts. A list of them, which attempts to be more specific and exhaustive, is presented in Table 12. Again, indicatively, the number of times these factors were taken in consideration in plans is presented opposite each factor.

This table highlights that national perspectives receive stronger emphasis with respect to aquaculture development. Whilst this is justified, the positioning of aquaculture products on international markets remains of prime importance in a strategy oriented towards exports. Few countries gave international market trends, potential competition amongst producers, along with international treaties are codes, the recognition they deserve in their planning processes.

It is suggested that the criteria listed in Table 12 could be used to guide the formulation of future national strategies and plans for aquaculture development.

Table 12: Assumptions and factors upon which to base projections with corresponding number of times encountered in country plans[1]

National context	
Analysis of past trends / results from past plans	5
Analysis of past and present domestic economic environment: - prices - incomes - demography	 2 0 1
Analysis of past and present domestic markets/demand/consumer preferences	3
Analysis of present natural resources and state of the environment (in relation to aquaculture): - carrying capacity - areas to develop - conflicts over resource use.	 3 (general) 2 2 1
Analysis of status of present production and transformation facilities.	1
Evaluation of present research capabilities and technical expertise.	2
Analysis of present legal and regulatory frameworks: - in place - to enforce - to create/develop	 0 1 2
Evaluation of present financial resources: - available and where from - to attract (and how)	 4 0
Analysis of trade-offs associated with each decision, evaluation of alternatives.	0
Clear separation between projections for the capture and the culture sectors	4
Overall evaluation of opportunities and constraints / SWOT analysis	6
International context	
Analysis of global / regional economic environment and economic trends: - evaluation of other country plans (comparison) - price trends for specific commodities - orientation of future demand (high-value vs. low-value products)	 3 1 1
Analysis of international markets: - evolution of import/exports trends - evaluation of potential future competition amongst products	 0 0
Explicit consideration given to international treaties and codes (e.g. FAO Code of Conduct for responsible aquaculture development)	1
Evaluation of international public opinion and environmental/social concerns.	2

[1] The figures corresponding to each criterion are subjective and as such, they should be treated with caution and viewed only as indicative of the weight given to the criteria in individual country plans.

3.3.3 What decision-making methods are most suitable, and in which context?

It is important to remember that, no matter how attractive the decision-making and consensus-building techniques may be, they bear a high cost, both in terms of time and money. Interestingly, all the references cited above concerned developed countries, where such resources may not be a limiting factor. Only one example of the development of a 'consensus' participation model (achieving both a collaborative consensus and including the disenfranchised poor in the process) in the case of planning the management of protected areas of a developing country – Zambia – was found (Warner, 1997). This may be an indicator that long, complex and costly decision-making processes may not be within the (financial) reach of a developing country, with little or no aquaculture.

The task of setting targets has been recognised as "formidable" given the diversity of factors, interests and possible changes to account for (De Silva, 2001: 450). Yet, more than hypothetical figures, targets indicate priorities, help to mobilise and allocate resources and introduce accountability (Christiaensen, Scott and Wodon, undated). The Delphi method, by having demonstrated its usefulness and practicality in reaching consensus and by being flexible may allow overcoming both the financial constraint and the difficulty inherent to target setting. Moreover, its adaptability to a wide range of contexts provides the additional benefit of incorporating both qualitative elements (to agree, for example, on the components of the framework or the strategy) and quantitative elements (e.g. fixation of production targets, development and implementation of activities, costing) in a single process.

4. CONCLUSIONS

4.1 Aquaculture forecasts

Findings suggest that answers to the two questions raised at the beginning of the study, namely: (1) do individual countries have a "realistic" ambition to expand their aquaculture production and (2) is the sum of national forecasts likely to be compatible with projected increases in demand for food fish, are generally positive. Countries do wish to expand aquaculture output, and with some exceptions, their assumptions were realistic. The examination of national plans and strategies has provided unique insights into the ambition and commitment of governments to develop aquaculture, and most have appeared to endorse the sector's growth. National priorities for development, in particular with regard to the role of aquaculture to contribute to food security (often cited as one of the three reasons behind a country's will to develop the sector, along with foreign exchange earnings and economic growth) was indicative of the realisation that aquaculture can be an innovative motor of growth with many additional benefits, whilst revealing growing concerns over over-exploitation of capture fisheries and the motivation to find alternatives to declining catches.

As for the second question, aggregation of national plans indicated that global forecasts underestimated the supply of fish food coming from aquaculture. China's future expansion is critical but using a modest 2 percent growth rate and without increases in food fish output from capture fisheries, results suggested that most of the demand projections would be met. Thus, aggregated country productions from aquaculture are expected to grow at an average annual growth rate of 4.5 percent over the period 2010–2030. From these findings, a conclusion, yet sanguine, may be that the aquaculture sector could replicate the expansion of agriculture. However, much depends on the realism of assumptions used to support projected targets, and countries formulating development plans for their aquaculture sector are encouraged to place a stronger emphasis on the rationale supporting their production forecasts. This is useful to improved sector development planning, at an international scale, and progress monitoring. Many factors affect the evolution of an activity like aquaculture and setting realistic production targets is a difficult task. The sector is susceptible to unforeseen shocks, meteorological, pathological or economic, when countries compete in marketing a commodity and expand their production simultaneously.

The level of accuracy of projections can only be assessed from the clarity and realism of the assumptions upon which they are based. The scrutiny of global projections requires explicit calculations and assumptions, which is not always the case for national aquaculture development plans. However, country plans and strategies reveal governments' commitment to aquaculture development. From this perspective, national plans may be more informative than global forecasts to gauge where future production impulses will originate and what will shape future regional development trends.

Whilst macro projection models were based on commodity prices, per capita incomes, rates of population growth and landings from capture fisheries to estimate future supply, population density could be another factor to take into consideration in the setting of future production targets. This is suggested through the examples of Norway and Brazil, for which low population densities are seen as an asset to develop aquaculture further whilst avoiding conflicts over resource use and social opposition as typically encountered in more densely populated areas.

Because the gap between the estimated requirements from aquaculture in the next decades and what countries' expected production was not large (even with a modest 2 percent annual growth for China), there may not be causes for immediate concern. Proper monitoring of aquaculture output should be maintained (or developed in countries where it is not yet in place). Technological developments could bring answers to immediate concerns over resource use: self-maintained offshore cages for intensive production (Mann, 2004), alleviating pressure from coastlines and inland waters, could significantly contribute to increases in aquaculture outputs and stabilisation of fish prices. However, potential for high profits from the farming of high-value marine finfish may be the prime motive behind this form of aquaculture and, in the case of the United States, it has been recommended that a moratorium is imposed on its development until "national aquaculture legislation is adopted and comprehensive, open and transparent regulations are finalized" (Belton *et al.*, 2004) to avoid loopholes and conflicts over the use of coastal and offshore resources. Further concerns may be voiced over the market allocation of this type of production. Targeting developed country markets with high value fish exports is often a prime aim for many developing countries. Balancing both domestic needs for extra protein provision in low-income, food-deficit countries, and foreign income generation from the same activity is likely to involve delicate and politically-challenging decisions.

4.2 Aquaculture planning

The third question addressed in this report dealt with planning processes. Appraisal of country plans and strategies revealed a generally weak planning process. This was mainly due to the fact that detailed information on the methodologies and procedures followed to complete a final plan were omitted or sketchily reported. This shortcoming would be easily fixed and the report has provided a planning framework of issues to address and which could be used directly by countries willing to develop or enhance their aquaculture sectors. Back-up by the application of the Delphi method as a consensus-building technique, not only would this greatly improve the quality of future plans, but would also enable an evaluation of their likelihood of success, as it has been demonstrated in the literature that transparency, legitimacy and agreement (reached through participation and consensus) were key to the success of a plan. It is also recommended that a more thorough assessment of past and present trends, at both national and international levels, are useful in determining more accurately areas with potential for development and in setting realistic production targets.

Beyond absolute increases in production, the sustainable development of aquaculture will depend on accurate and sensitive planning as issues of resources allocation for production and distribution of production will generate debate and require compromises. Much has been written on the concept of "sustainable development" and its irreconcilable goals of economic growth and development on one hand, and ecological (also social and economic) sustainability of the other – what Robinson (2004) has referred to as "squaring the circle". Aquaculture development could be seen in this sort of dilemma, and like the impossible mathematical problem, will require new tools to be solved. These new tools call for "a process by which [multiple conflicting objectives] can be expressed and evaluated, ultimately as a political act for any given community or jurisdiction". Planning will therefore be key to the sustainable development of aquaculture as it "encourages the development of new modes of public consultation and involvement intended to allow multiple views to be expressed and debated" (*ibid*, p. 382). Technical progress will undoubtedly play a crucial role in supporting aquaculture development, but its direction and (re)orientation will have to be constantly revisited through decision-making processes. By extension of Robinson's argument, the sustainability of aquaculture and it fulfilling world's expectations as a supplier of fish for food security and as a vector of economic development is more likely to be "a political act", than a scientific achievement.

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Appendix 1: Summary of contents of country plans

Horizon: in bracket is the year the projections were made (used as baseline).
Full references of documents used are presented in Appendix 2.
Countries are presented in alphabetical order.

	BANGLADESH
Horizon	Two documents available: (2002)–2007 (6th five-year plan) (2001)–2020 (aquaculture development plan)
Projections (quantified)	6th five-year plan: *Freshwater aquaculture* output = 1 466 750 tonnes *Shrimp culture* output = 170 000 tonnes. Total output = 1 636 750 tonnes. (+ 16 percent *per annum* compared to 11 percent *per annum* during the previous plan). Aquaculture development plan: + 3.5 percent average *per annum* (from 296 000 tonnes produced in 2000–01 to 1 340 000 tonnes in 2019–20).
Species	Shrimps, carps, pangas, rajpunti, tilapia.
Methodology	Analysis of past plans and failure. Evaluation of development potential of various fisheries sub-sectors by documents authors.
Assumptions	Use of forecasted population and per capita fish consumption growth. No indication about price variations. (Expected total income from increased production calculated on the basis of average price of Tk80 per kg – fixed over plan duration).
Means of achievement	**Prices:** Not specified **Markets:** Shrimp for export markets. Inland aquaculture production for domestic markets. **Environment:** *Freshwater aquaculture:* Re-excavation, rehabilitation and restoration of all public water bodies for improvement and maintenance of healthy fish production. 39 percent increase in area combined with a 40 percent increase in yields. Optimal use of inland waters. *Shrimp culture*: Implementation of environmental management measures for the sustainable exploitation of coastal areas (coastal aquaculture). Integrated management to limit externalities from and to other users. Extend area under cultivation to 230 000 ha. **Regulations:** *Freshwater aquaculture*: leasing of government tanks, ponds etc. to targeted poor and unemployed youth. Provision of supervised credit. *Shrimp culture*: equal package of incentives as other export-oriented industries. Introduction of shrimp-crop insurance. Credit at low interest rates, tax free income and tax holidays, integrated land policy. **Development/Promotion:** Increased investments in research. Target farmers for credit provision and technical extension as NGOs tend to focus on the landless. *Freshwater aquaculture*: development of private-sector hatcheries and nurseries. Strengthening of extension and training programmes. Integration of aquaculture with household farming. Shrimp culture: Establishment of private hatcheries and distribution network, appropriate farm design and technology. Other quantitative technical requirements: 216 million fingerlings of 10–12 cm size. 450 million spawn (shrimp farming) 3 million tonnes of fish feed (for both fish and shrimp production).
Constraints to overcome	Ensured supply of fish feed, selection of high-yielding broodstock, fish health management, multiple ownership of ponds and water bodies, complex credit norms, weak institutional capabilities in aquaculture development.

	BRAZIL
Horizon	(2003)–2006 (grouped with capture fisheries)
Projections (quantified)	Total aquaculture output = 640 870 tonnes (+ 22 percent average *per annum* – calculated with foreseen annual increase of 22 percent from 2001–2002 figure of 210 000 tonnes). *Tilapia* (2010) > 420 000 tonnes (+ 25 percent average *per annum*). Consumption = 12 kg per capita per year.
Species	Shrimp and tilapia.
Methodology	Examined natural resources, past growth and per capita consumption. Diagnosis of main problems.
Assumptions	Deficit in fish in 2010 = 25 million tonnes estimated from population growth and consumption of 14 kg per capita per year.
Means of achievement	**Prices:** Reduction in price of primary products. **Markets:** multiply by 3 value of aquaculture and capture products. Multiply by 3 the value of exports to US$387 million between 2002 and 2006. Target markets not specified. **Environment:** widely available freshwater resources (8 percent of world freshwater resources) and suitable tropical climate. Saltpans available for shrimp in NE. **Regulations:** Guidelines to set up tilapia farms to be developed, land tenure rights to adapted, sanitary legislation to be developed. **Development/Promotion:** modernisation of entire production chain. Creation of 500 000 jobs (including 152 300 in tilapia production by 2010), multiply income generation by 2 between 2003 and 2006. Increase per capita consumption to level recommended by FAO (12 kg per capita per year.). For *tilapia production*: private investments = 81 million Real + public funds = 5.7 million Real (hatcheries, processing plants, feed etc.)
Constraints to overcome	Structural problems, low productivity, small farms. Conflicts over water resources. Lack of: trained labour, formulated feeds, suitable financing means and investments, sanitary controls, producers' organizations. No policies for most productive species.

	CANADA
Horizon	(2001)–2006 (freshwater aquaculture) (2000)–2015
Projections (quantified)	Total aquaculture output = 577 000 tonnes (+ 5 percent average *per annum*), including: *Salmonid output* = 350 000 tonnes (+ 9.9 percent average *per annum*). *Cod output* = from 0 to 128 000 tonnes (> 200 percent average *per annum*). *Freshwater aquaculture* output: Pessimistic = 10 100 tonnes (+ 0.5 percent *per annum*) Average = 14 700 tonnes (+ 6 percent *per annum*) Optimistic = 26 000 tonnes (+ 15 percent *per annum*)
Species	Salmon and cod as main finfish species. Mussels and oysters as main shellfish species.
Planning methodology	Strategic planning workshop with industry and government experts. Not specified for freshwater aquaculture projections.
Assumptions	**Markets:** US imports of farm raised fish and seafood increase at 15 percent annually. Canada maintains 45 percent of market share with the USA. Consumer confidence is upheld and reinforced. **Environment:** The environmental sustainability of the sector is achieved. The industry has secure access to development sites. **Regulations:** Federal and provincial governments establish an appropriate policy framework. Not specified for freshwater aquaculture projections.
Means of achievement	**Prices:** Not specified. **Markets:** Not specified **Environment**: For *cod production*, development of 4 to 6 commercial cod hatcheries capable of producing 40–45 million juveniles per year. Grow-out sites required: 120 of 20 ha each (2 400 ha). For *salmon production*: only 66 new salmon sites of 12 ha each (792 ha). For *freshwater production*: demonstration of low polluting impact of current production processes through R&D. **Regulations:** For *freshwater production*: update of current legal framework based on recent results from R&D to minimise environmental impacts. **Development/Promotion:** Growth of the sector at a rate of 11 to 17 percent annually. New species expected to emerge in commercial quantities: cod, halibut, sablefish (black cod) and wolfish. Diversification toward cool freshwater species (trout and Arctic charr) and other 'specialty' species. Improve production on existing sites and develop new ones.
Constraints to overcome	General constraints: perceived conflicts in mandates (policy framework), resources (financial and human). For *freshwater production*: strong regulatory framework aiming at minimising environmental impacts and issues of sharing water resources.

	CHILE
Horizon	(2003)–2013
Projections (quantified)	*Salmon* output to double (= 0.9 million tonnes, + 7.2 percent average *per annum*)
Species	Salmon mainly. Other competitive species include abalone, oyster, hake, seaweeds, turbot
Methodology	Delphi Method (180 experts from private, public and academic sectors)
Assumptions	Increase in the nominal price of Atlantic salmon in the next 10 years to US$3–4 per kg[6].
Means of achievement	**Prices:** Not specified. **Markets:** 1) increase market; then quality certificates and value added; 2) increase domestic market, 3) reinforce coincidence of Chilean salmon with the positive attributes of Chile, 4) export to new markets (China, Europe, USA, and Latin America, esp. Brazil). **Environment:** NOT use transgenic salmon; control industrial wastes and development of vaccines; minimal use of antibiotics (natural methods of disease control used instead). **Regulatory:** simpler procedures for permits and less speculation, take account of other coastal users (tourism), differentiate license fees for species and regions, and regulate the use of genetically modified organisms. **Development/Promotion:** finance capacity, research and technical transfer, develop infrastructures, enhance free trade, risk/venture capital; develop vaccines, feed alternatives, genetic improvements, native species, feed manufactured entirely in-country.
Constraints to overcome	Trade barriers and dumping accusations, ecological challenges, shortage of R&D, conflicts over the coastline and excessive regulation, and short time horizon of companies.

	CHINA
Horizon	(2000)–2005 (10th five-year plan); 2010–2020 (FAO estimates)
Projections (quantified)	Output 2005 = 30.8 million tonnes 51 million tonnes (+ 2.2 percent average *per annum*) Consumption = 36 kg per capita (+ 1.2 percent *per annum*). For rice-fish production: target of 1 500 kg fish + 15 000 rice per ha).
Species	Not specified.
Methodology	Panel of experts (academics, industry representatives and government officers). Public participation.
Assumptions	Growth rates achieved during past plan in addition to changes and reforms and international situation (e.g. WTO accession).
Means of achievement	**Prices**: Not specified **Markets:** Introduce market incentives. Increase investment in infrastructures to secure development momentum. **Environment:** Intensification of use of inland water bodies (development of cage aquaculture in reservoirs, upgrading of pond conditions), increase of areas used (e.g. paddy fields), encouragement to use wastewater, development of poly-culture. **Regulations:** Strengthening of legal framework and institutional capacities. Enforcement of measures to protect resources and the environment. **Development/Promotion:** Restructuring of the whole fisheries sector to improve quality and increase income (not increase production) to add value to the sector. preferential loans, fiscal conditions and improved technical support to operators, extension of the use of manufactured feed pellets to reduce eutrophication, transformation into a professional industry with producers associations, upgrading of the national technological base. Strengthening of scientific research, education and training to improve research capability. Preparedness for emergencies.
Constraints to overcome	Unclear.

[6] 2002 price for Atlantic salmon was US$ 2.7 per kg.

	EGYPT
Horizon	(2000)–2017
Projections (quantified)	Output = 810 000 to 870 000 tonnes (+ 5.5 percent average *per annum* to achieve 840 000 tonnes). Consumption = 14 kg per capita.
Species	Freshwater species (Nile tilapia, carps, catfish). "Highly-productive strains adapted to culture conditions".
Methodology	Not specified. No apparent public participation.
Assumptions	Future output needed based on human population projections, with consumption levels kept constant at 2000 levels (11.3 kg per capita). No assumption on prices.
Means of achievement	**Prices**: Not specified **Markets:** export markets (high-value fish) to develop. **Environment:** No reliance on the development of marine aquaculture (shrimp and finfish) to increase overall production (competition for suitable sites and constrained by collection of wild seed). Use of aquaculture to rehabilitate saline lands, use of genetically-improved fish species (e.g. tilapia) not excluded. No new development in the Nile Delta and culture of high-value species in cages along the Red Sea. Emphasis on rice-fish farming and drainage water re-use. Intensification of production before horizontal expansion. **Regulations:** strong regulatory framework to control farm development (pollution) already in place, change in the law banning first use of freshwater in fish farms to be considered. **Development/Promotion:** Hatcheries under development to kick-start the marine aquaculture sector. Diversification of brackish aquaculture to incorporate some marine species (e.g. European seabass).
Constraints to overcome	Conflicts over resource use (priority for land and water resources given to agriculture, land and freshwater availability). Marketing and economics (drop in farm gate prices, increases in production costs), current limited access to foreign markets, mostly small to medium farms.

	INDIA
Horizon	(1995)–2005 (freshwater aquaculture)
Projections (quantified)	Freshwater aquaculture output to double: from 1 512 000 tonnes in 1995 to 3 312 800 tonnes in 2005 (*Operation Aqua-Gold, "Matsyavardhan*") (+ 8.2 percent average *per annum*).
Species	Major carps (Indian, Chinese and common carp), with other species of fish and shellfish (minor carps, catfishes, freshwater prawns according to availability and demand in different states).Ornamental fish and freshwater pearls also considered for diversification.
Planning methodology	Extrapolations based on available statistics, previous publications and the seven document authors' experience in the field.
Assumptions	Duly consideration given to resources, prevalent production levels and consumer preferences in the preparation of the blue print for development "Operation Aqua-Gold" (Matsyavardhan). Increased demand and fish consumption (linked to population growth). Average productivity increase (to 2.76 tonnes per ha per year). Flexibility of operation and scales of investments, compatibility with other farming systems and high potential of eco-restoration (organic recycling and waste treatment) make freshwater aquaculture a fast growing farming activity in India.
Means of achievement	**Prices:** Not mentioned. **Markets:** no mention (apart from increase national demand). **Environment:** Increase in areas used for aquaculture by 45 percent (from 0.83 million ha to 1.2 million ha) and increase in productivity by 50 percent (from 1.83 tonnes per ha per year to 2.76 tonnes per ha per year - achieved in all agro-ecological conditions of the country). **Regulations:** Implementation of the Blue-print strategy plan "Operation Aqua-Gold" (Matsyavardhan) over 5 years from 2000 (assumed). More discussions with development agencies, mainly the State Fisheries Departments. **Development/Promotion:** Requirement of 15 362 million fry and 5.2 million tonnes of feed to support the achievement of the above targets.
Constraints to overcome	Not specified.

	INDONESIA
Horizon	(2003)–2009
Projections (quantified)	Output to double (= 2.9 million tonnes, + 11.1 percent average *per annum*) Consumption to be multiplied by 1/3 Income from exports to be multiplied by 9.
Species	Shrimps?
Methodology	No apparent public consultation
Assumptions	Unclear (no mention of prices)
Means of achievement	**Prices:** Not mentioned. **Markets**: market support and business partnerships. **Environment:** develop potential of freshwater, brackish and marine resources. **Regulatory:** Unclear. **Development/Promotion:** Emphasis on the involvement of the private sector: “development of aquaculture business system” and establishment of a conducive business environment. Five specific programs for aquaculture development: 1. Intensification (“Inbudkan”) (for exports and food security); 2. Integrated aquaculture (increase fish farmers’ income and welfare, in line with the Code of Conduct for Responsible Fisheries). 3. Rural aquaculture (optimisation of backyard activities in rural areas); 4. Culture-based fisheries program (to increase open water productivity). 5. Green productivity program (overlaps with the previous programs, aims to “motivate green productivity and implement the CCRF).
Constraints to overcome	Market globalisation, regulations and laws, lay-out of aquaculture zones, capital, extension institution, marketing and distribution, technologies, security and culture facilities/infrastructures.

	PHILIPPINES
Horizon	(2001)–2004
Projections (quantified)	Increase output to 663 000 tonnes (+ 15.1 percent average *per annum*).
Species	Finfish and crustaceans
Methodology	Philippine Fisheries Industry Plan (1999–2004) drafted during a consultative meeting with stakeholders and validated by fishery experts. This plan was then used in the formulation of the Aquaculture Research, Development and Extension Agenda (document obtained).
Assumptions	Past environmental damage, disease and possible effects on commercial fisheries from shrimp and cage milkfish taken into account.
Means of achievement	**Prices:** Not specified. **Markets:** Not specified. **Environment:** Develop an ecologically-sound and profitable aquaculture sector through improved stocks and new culture species, sustainable management of aquaculture resources. Expansion to other production zones, intensification, shift from close to open systems. **Regulations:** Enhance regulation and vigilance on territorial use rights in fisheries (TURF). **Development/Promotion:** Enhance technology transfer systems, training and upgrading of aquaculture human resource, pilot-testing and verification of aquaculture technologies, development of biological and non-biological health management systems, development of superior stocks from traditional and new species through genetic selection and hybridization.
Constraints to overcome	The Plan was recognized as ambitious. Space limitations in brackish aquaculture and growing concerns for environmental protection and management (acknowledgement of past environmental degradation). Technical constraints: poor quality of seed stock and diseases. Socio-economic constraints: costs of inputs, financing and marketing, land use. Lack of research and unknown impacts of imported technologies on national aquatic resources.

	THAILAND
Horizon	(1996)–2010
Projections (quantified)	Total aquaculture output = 704 349 tonnes (+ 1.7 percent average *per annum*), including: *Freshwater aquaculture* output = 299 988 tonnes (+ 2.0 percent average *per annum*). *Coastal aquaculture* output = 84 453 tonnes (+ 1.6 percent average *per annum*).
Species	Nile tilapia, catfish, shrimp (*P. monodon*), green mussel and oyster; high-value species such as groupers, mudcrabs, squids.
Methodology	No apparent consultation though a "consensus" is mentioned.
Assumptions	For all species, domestic price assumed constant (1992–2001). 2001 value of 64 percent of total production from freshwater aquaculture kept constant in 2010 forecasts
Means of achievement	**Prices:** Not specified. **Markets:** Freshwater production for domestic market, coastal species for both domestic and export markets. Recognition that products must be competitive and that new markets, other than the USA and Japan, have to be found. **Environment:** Concern over intensification and use of the coastal zone. **Regulations:** Enforce existing laws and regulations, cooperation with NGOs. . **Development/Promotion:** Technological improvements such as use of genetic manipulation to improve high-yielding strains of both freshwater and coastal species. Linkages, strengthening and budget supporting to research and educational institutions
Constraints to overcome	Adequacy of infrastructures, financial resources, skilled labour. Disease, environmental constraints (pollution) and competition. Governmental and public appreciation of the importance of the sector. Poor communication between the aquaculture industry and the communities, compatibility of Thai aquaculture with responsible environmental stewardship.

	VIET NAM
Horizon	(2001)–2010
Projections (quantified)	Output = 2 000 000 tonnes (+ 10 percent average *per annum*).
Species	Not specified.
Methodology	Not specified (assumed based on past growth of the sector)
Assumptions	Increase in population and purchasing power.
Means of achievement	**Prices:** not specified **Markets:** Orientation towards a "market-oriented economic system". Improvements in efficiency, value adding activities, increased industrialisation and modernisation. **Environment:** 300 000–350 000 hectares of water suitable for aquaculture and not yet exploited. Stop misusing natural resources. Compliance with national and international environmental standards for eco-labelling and certification of aquaculture products. **Regulations:** Provision of appropriate legal and administrative structures. **Development/Promotion:** Economic reform process to accelerate, public sector to support the private sector.
Constraints to overcome	Not specified.

Appendix 2: Notes and country plan references

Europe includes the 15 countries in the European Union as of April 2004; Austria, Belgium, Denmark Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and United Kingdom (Great Britain); plus Eastern Europe, and Western European countries not members of the European Union (i.e. Norway).

Latin America and Caribbean (LAC) includes 13 countries in South America: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guyana, Guyana, Paraguay, Peru, Surinam, Uruguay, Venezuela; 8 in Central America: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, and 15 in the Caribbean: Bahamas, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago, Turks and Caicos Islands, US Virgin Islands.

South Asia (excluding India) consists of Afghanistan, Bangladesh, Maldives, Nepal, Pakistan and Sri Lanka.

South-East Asia includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand and Viet Nam.

Sub-Saharan Africa includes Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Democratic Republic of Congo, Republic of, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Sao Tomé and Príncipe, Sénégal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

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