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Gloom and doom? The future of marine capture fisheries

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Predicting global fisheries is a high-order challenge but predictions have been made and updates are needed. Past forecasts, present trends and perspectives of key parameters of the fisheries—including potential harvest, state of stocks, supply and demand, trade, fishing technology and governance—are reviewed in detail, as the basis for new forecasts and forecasting performance assessment. The future of marine capture fisheries will be conditioned by the political, social and economic evolution of the world within which they operate. Consequently, recent global scenarios for the future world are reviewed, with the emphasis on fisheries. The main driving forces (e.g. global economic development, demography, environment, public awareness, information technology, energy, ethics) including aquaculture are described. Outlooks are provided for each aspect of the fishery sector. The conclusion puts these elements in perspective and offers the authors' personal interpretation of the possible future pathway of fisheries, the uncertainty about it and the still unanswered questions of direct relevance in shaping that future.

Keywords: future; governance; scenarios; fisheries; sustainability

1. INTRODUCTION

Since the creation of FAO in 1945, the world has evolved dramatically and the change is accelerating, affecting what society wants or could achieve and what it does in practice. Fisheries, in particular, have undergone revolutionary mutations through progressive technological innovation, exponential development of fishing capacity, geographical expansion, development of an intense international trade and an innovative legal framework, the 1982 Law of the Sea Convention. Fisheries have increased their contribution to human livelihood and food security, maintaining or improving the international terms of exchange, paying a heavy toll in human lives and environment degradation. Most fishery resources suffered more than advisable and some collapsed, affecting the sector's economic viability and profoundly modifying the ecosystem, sometimes perhaps irreversibly. Owing to genuine public concern, enhanced through the activism of environmental NGOs, the romantic image of the courageous and adventurous fisher fighting against the generous, beautiful but treacherous sea has been progressively tarnished and fishers are now often presented as blind, greedy and irresponsible predators inflicting a major negative impact on the marine ecosystem.

The scientific literature contains numerous diagnoses of the widespread management failures and abundant prescriptions for improvement (Larkin 1972; Stevenson 1973; Johnston 1992; FAO 1993; Walters 1995; Garcia 1992; Alverson & Larkin 1994; Garcia & Grainger 1997; Garcia & Newton 1997; Mace 1997; Williams 1998; Sutinen & Soboil 2003).

This grim picture is not unique to fisheries; agricultural, forestry and freshwater resources, as well as the atmosphere, are also in a similar if not more serious and threatening situation (WRI 2002*a*; FAO 2003).

Fisheries are still evolving in various ways, at varying paces in different places and their future, shaped by internal and contextual driving forces and pressures, is both complex and uncertain. Institutional progress has been impressive, but the expected outcomes are slow to materialize owing to the necessarily slow response time of complex socio-economic and ecological systems. The effectiveness of what has been done cannot be easily measured, and yet further critical action is called for, with high potential socio-economic short-term costs for politicians. A profusion of miraculous prescriptions is provided by well intentioned 'doctors' but practical experience is still limited. Exacerbated by the growing and well orchestrated media pressure, societal impatience grows with its awareness as hard-pressed policymakers attempt to identify critical issues and alternative pathways.

In this context, the present value of information about the future increases significantly, providing the incentives for forecasting, despite the shortcomings of the enterprise. Chapman (1970) held that the task of forecasting fisheries' future developments was facilitated by the fact that long-term global trends tended to be slow, persistent and consistent. However, all modern futurists would agree with Gallopin that it would be suicidal to consider the future as a simple extrapolation of the present. Niels Bohr, for instance, deduced, ironically, that 'all prediction is difficult, particularly about the future' (cited by Pope 1989), and predicting the future of any human activity and socio-ecological system is generally recognized as a precarious, tentative and highly subjective enterprise (Larkin 1991; Gallopin 2002). Two main difficulties are encountered in predicting the future of fisheries.

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One contribution of 15 to a Theme Issue 'Fisheries: a future?'.

(i) Forecasting methodology and underlying models. It is unlikely that any mathematical algorithm could satisfactorily capture the complex, chaotic, nonlinear and often undetermined nature of the fisheries' socio-economic and environmental systems. This is particularly true at the global level. Consequently, seemingly well grounded predictions may easily fail while some of the most interesting developments might remain unforeseen.

(ii) It is impossible to predict the future of fisheries without a reliable prediction about the future of the world itself, an even higher-order challenge.

This document deals only with marine capture fisheries, referring only superficially to aquaculture in terms of its potential interactions. It reviews past forecasts, present trends and outlooks for single aspects of the fishery systems, as well as more comprehensive scenarios. After looking briefly at the driving forces that condition world developments, it reviews the types of scenarios available for the future evolution of the world itself and by inference, for fisheries, before concluding on the most likely pathway for the sector in the next decades.

2. PAST FORECASTS, PRESENT TRENDS AND PERSPECTIVES

The following review of the past attempts to predict the future of fisheries should provide a way to probe our capacity to forecast the evolution of the sector. Many of the forecasts made in the past have been tested by time. Some of the most recent ones are still to be tested in the future.

(a) *Marine fisheries potential*

The earliest predictions of world fisheries often focused on global potential harvest (e.g. MSY) as a target, progress towards which was a relative measure of development. The estimates evolved from the precise but inaccurate 22 mt in the early 1950s (Thompson 1951) to a range of 55–115 mt in the early 1960s (Kesteven 1963), a more confusing range of 20–1000 mt in the early 1970s (Chapman 1970; Sprague & Arnold 1972), reflecting the widening range of methods used[1] and rapidly stabilizing afterwards to the largely adopted forecast of 80–100 mt made by FAO in the early 1970s (Gulland 1972; Robinson 1980, 1984). More recently, Grainger & Garcia (1996) estimated such potential to be *ca*. 100 mt, with a minimum of 80 mt and an unlikely maximum of 125 mt. Both Gulland and Chapman underestimated by *ca*. 10–15 years the time needed by the sector to reach the potential[2] (underestimated the rate at which resources would decrease under growing fishing pressure) but rightly foresaw the sharp decrease in the annual expansion rate of fisheries. Deep-sea resources, not intensively exploited at the time, are probably poorly represented in these estimates. They represent an unknown but limited additional potential and for those in the high seas, possibly also a serious management problem (Moore 1999).

Natural oscillations in ecosystem productivity have a significant impact on the resources and the fisheries and may result in faster depletion and slower recovery. Oscillations of *ca*. 55–60 years have been detected in the North Atlantic and North Pacific for species such as herring (*Clupea harengus*), cod (*Gadus morhua*), sardine (*Sardinia pilchardus*), anchovy (*Eugralis* spp.), salmon (*Salmo* spp.), Alaska pollock (*Theragra chalcogramma*), as well as Chilean jack mackerel (*Trachurus murphyi*),[3] with phase opposition between the two areas (Klyashtorin 2001). Predictions up to 2040 of the respective rises and falls in the two areas (in the range of 5–20 mt) indicate that, overall, the total catch of these species would first increase by *ca*. 6 mt (until 2015) and then decrease by *ca*. 3 mt by 2040.[4] Overall, all other factors remaining unchanged, the important but opposed variations of the main and most variable species will affect total supply in a manner that is quantitatively globally negligible (albeit locally significant) and similar to what has been experienced since 1950. If the global fish trade system is reactive enough, these oscillations might not significantly affect availability and prices, particularly as the variations in the other two-thirds of the world catch, consisting of more than 500 species, is buffered by their diversity. Influences at lower frequencies (e.g. related to cosmic oscillations), might become evident in the future.

Longer-term climate change will affect the ocean environment and its capacity to sustain fishery stocks and is likely to exacerbate the stresses on marine fish stocks, from fishing and other marine or land-based activities. The extent to which it will affect fisheries, in the different regions and species, is however not yet clear. Productivity might increase or decrease significantly. Ecosystem boundaries may be displaced and species composition may change remarkably (e.g. Blanchard & Boucher 2002). In polluted areas, oxygen depletion will be aggravated, particularly if flooding facilitates the flow of pollutants to the sea. Fisheries infrastructures may have to be displaced, at high cost. Fisheries lacking mobility (e.g. small-scale fisheries) might suffer the most. Freshwater flows will be modified. New diseases may be introduced. Assuming such changes will occur more slowly than the already experienced natural variations, there should be little additional impact on supply/demand and prices. However, the existence of flexible management systems and access agreements between neighbouring countries would facilitate the adaptation to change (Everett *et al.* 1995). More practically, the eventual impact cannot yet be accounted for but must be regarded as a major source of 'surprise'.

Non-conventional species are often mentioned as an additional source of potential. Both Chapman (1970) and Gulland (1972) mentioned that proper use of krill (100 mt), lantern fishes and squids might raise the potential of marine fisheries to 200 mt. In the early 1970s, Sprague & Arnold (1972) considered that opening new fisheries in the Indian and Antarctic Oceans, improving management and harvesting lower trophic levels of the ocean food chain, marine fisheries alone could produce as much as 400 mt, including 50–100 mt of octopus and squid, 50–75 mt of krill and 100–150 mt of mesopelagic and deep-sea fish. They deduced that mobilization of the latter type of resources would take 40–50 years (i.e. would materialize by 2010–2020). The already well developed exploitation of cephalopods, now hampered by the international ban on large-scale driftnet fishing, does not seem able to uphold that forecast. Krill and mesopelagic fishes have been only moderately used, and the validity of the forecast remains to be tested. Considering the experience acquired since the 1970s and the potential problems related to the integrity of the ecosystem's trophic chain, the potential of unconventional resources is considered as very limited.

Large cetaceans have been very significantly affected by human hunting, leading to the extinction of a few species and quasi-extinction for many others. Following decades of protection, however, and despite various management loopholes allowing some hunting to continue on some species, several species and populations are still very abundant (e.g. minke whales, *Balaenoptera acurostrata*) or have recovered to high abundance levels. This has led to the question of increased or renewed exploitation for human food, arguing that these animals compete with humans for food and indeed harvest more fishes from the oceans than humans do. According to Tamura (2003), marine cetaceans consume at least 249–434 mt of seafood, and their consumption of fishes represents from 66% to 144% of human harvest. Others argue that the species composition of the human and cetacean harvest overlap only partly and the argument is far from closed. It is being proposed (and argued against) that a general reopening of whaling would increase the availability of fishery resources. This would require reaching a global consensus, which today seems unlikely, and unilateral actions have already been taken.

(i) *Outlook*

There is widespread agreement that, considering the officially declared marine fisheries landings with all their shortcomings (*ca*. 80–90 mt), the estimated discards (presently less than 10 mt),[5] the amount likely to be presently caught by IUU fishing and the impossibility of optimizing the production of all species simultaneously, the most likely potential of conventional marine species (80–100 mt) has indeed been reached some time ago (probably in the 1970s) and is unlikely to change in the next 20–30 years.[6] There is also broad agreement that the present global fishing capacity is in excess of that needed to extract potential sustainable catches.

Producing significantly more would require that the present pattern of fishing be dramatically modified; significantly increasing fishing pressure on already depressed top predators, reducing the abundance of those presently abundant cetaceans to reduce their consumption, further altering the ecosystem species composition by increasing the abundance of prey, thereby allowing an increase in their harvest. Improved technology would be needed to catch and process unconventional resources (e.g. mesopelagic fish species and krill) to turn them into acceptable edible products. This would, however, accentuate the 'fishing-down-the-food-chain' strategy, pushing it to its limits with uncertain ecological consequences, including unstable (hyper-fluctuating) ecosystems driven by climatic variations with local cycles of glut and scarcity and possibly massive oxygen depletion in coastal areas as unconsumed plankton settles and rots. Industry may adapt itself to the situation through flexible multipurpose catching and processing technology, managing to collect and process massive plankton biomasses for human and animal food. It is doubtful though that such a path will be globally acceptable.

(b) *State of resources*

Since 1974, FAO has produced a quasi-biennial report containing a compilation of the conventional assessments available for world fish stocks and other resource aggregates. The latest analysis of the situation (Garcia *et al.* 2004) indicates that, in 2003, approximately half the world's stocks are exploited at or close to their maximum, and *ca*. 25% of them are exploited either below of above such maximum (figure 1). The trends for 1974–2003 show that the proportion of stocks exploited below their capacity decreased with time, whereas those exploited above it increased steadily, as one would expect, owing to growing fishing pressure. No improvement is yet visible. The proportion of stocks exploited at about their maximum level of sustainable production has been stable at *ca*. 50%.

An update of the comprehensive analysis of the fishery statistics time-series collected by FAO since the early 1950s undertaken by Grainger & Garcia (1996) is given in figure 2. This shows that: (i) undeveloped resource fisheries, producing much less than their potential, decreased rapidly to zero by the middle of the 1970s; (ii) developing resource fisheries, with increasing landings but still producing less than their potential, increased until 1970–1990 and then decreased; (iii) mature resource fisheries, nearly producing their potential, increased until the 1980s and seem to have decreased since then; (iv) senescent resources, producing consistently less than their historical maximum, increased regularly since 1950, stabilizing perhaps during the last decade at *ca*. 30%. If we include in this category the recovering resources (identified in this analysis for the first time), i.e. those showing an increase in production following a period of consistently low landings, this percentage reaches 32–36%.

The two analyses referred to above use different terminologies owing to the different source data and methodologies used and possibly the interpretation of the results. The correspondence is given in table 1. To facilitate the comparison between the results yielded by the two approaches, the second set of results has been re-elaborated (figure 3).

The pictures obtained from the two approaches may be compared with caution, considering that the stock assessments are available until 2003, while the statistics are only available up to 2002 and the total periods covered are different. Nonetheless, the results for 2003 (figure 3*a*) and for the common period 1974–2000 (figures 1*b* and 3*b*) are similar. The analysis of catch statistics tends to give higher values (+10%) for underexploited and overexploited stocks and lower ones (−20%) for fully exploited stocks. Both analyses show no real improvement in overfishing, although the statistical trends point to the beginning of a modest recovery (figure 3, top right angle).

(i) *Outlook*

The pressure on the resources keeps increasing and shows no sign of abatement yet. The slowly increasing percentage of stocks recovering (whether owing to improved management or climatic conditions) is encouraging but is still too recent a phenomenon from which to draw hard conclusions. Many individual stocks and the fisheries exploiting them, for which detailed data are not available (particularly on coastal small-scale fisheries), would show a much more depressing picture. A simple

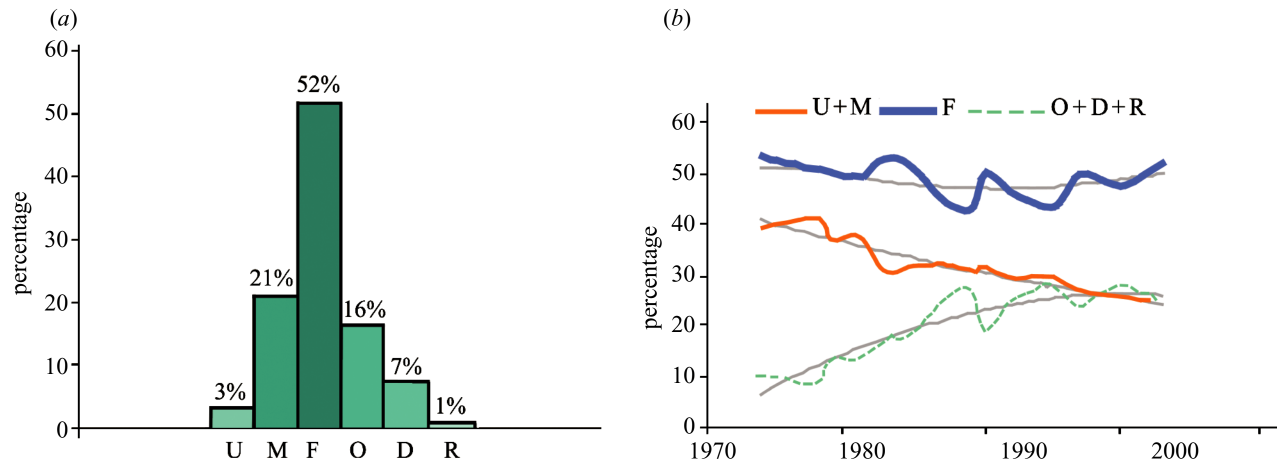

Figure 1. State of world fish stock items in (*a*) 2003 and in (*b*) 1974–2003. U, underexploited; M, moderately exploited; F, fully exploited; O, overfished; D, depleted; R, recovering.

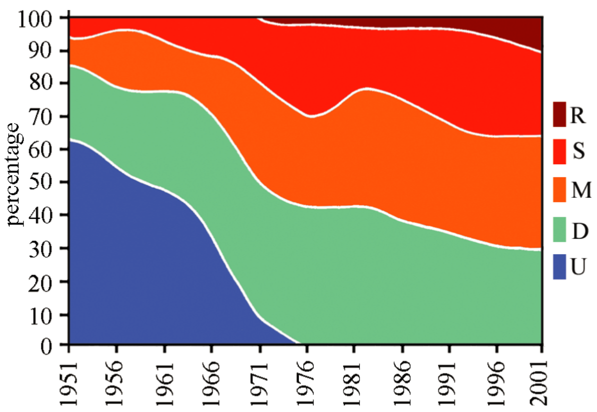

Figure 2. Percentage of major marine fishery resources in various phases of development with five-year intervals: 1950–2001. U, undeveloped; D, developing; M, mature; S, senescent; R, recovering. (Modified from Grainger & Garcia (2004).)

extrapolation of observed trends leads, at best, to a poor *status quo* situation, with *ca*. 40% of fully exploited stocks, 30% of overfished and underfished stocks, respectively, and several unexpected collapses of highly stressed stocks. Improvements in governance frameworks during the past three decades and the decline in building rate of large vessels (see § 2g) have not yet had any repercussion on the global state of stocks, even though some countries show signs of improvement.

One concern is that, having depleted large valuable stocks, fishing has redirected some effort and added a lot of it on other species lower down the food web. The strategy was advocated in the 1970s to increase fisheries production (Sprague & Arnold 1972). The consequence for change in catch composition and implications for the ecosystem were noted by FAO in the mid-1990s and in 2000 (Garcia & Newton 1997). The phenomenon was thoroughly investigated by Pauly *et al.* (1998)[7] and by Caddy & Garibaldi (2000).

The pressure in support of stock rebuilding can only increase exponentially as fisheries issues become environmental ones and a significant improvement should be expected, certainly in the developed world, perhaps in the developing one. Monitoring and diagnosis of the state of stocks and elaboration of management advice will continue to be complicated by natural oscillations and climate change. Management systems will become more competent in predicting changes but are still far from the type of responsiveness needed to adjust rapidly to systematic forecasts.

(c) *Aquaculture*

It is impossible to discuss the future of capture fisheries without referring to aquaculture. The production of conventional capture fisheries being naturally limited to 80–100 mt, the large predictable gap between future supply and demand will condition the future of fisheries in many ways, influencing prices, incentives for development, management costs, compliance and state of resources. Aquaculture is considered in all forecasts as the only reliable sustainable additional source of supply. In a well mediated review, *The Economist* (August 2003, p. 21) summarized this as 'If the past history of agriculture is of any guide, aquaculture will surely find a way to meet the world's demand for fish'. This sector has indeed demonstrated a strong potential for growth during the past two decades and will be a strong regulator of the supply chain in the future. It will therefore be a central conditioning factor of the future of marine fisheries and its growing production, functioning as a 'cooling agent' in the price formation process and in the chain reaction leading to overcapacity and overfishing. Increased supplies will come from an increase in the number of countries joining the production process, an expansion of the areas cultivated and an intensification of the processes (in yield per unit of area or volume). The supply gap might be filled by aquaculture in two ways:

(i) *by the top*—through production of high-value carnivore species, luxury items for the high-end market, requiring large quantities of fishmeal or other high protein meal for their culture, causing a rise in fishmeal and oil prices and creating further incentives to over-harvesting small pelagic and other prey species. As these tend to be also staple food for the poorest people, this development might lead to direct competition with them for food species.

Table 1. Correspondence between development stages and their relation with MSY.

method	categories				
stock assessments	underexploited	moderately exploited	fully exploited	overfished and depleted	recovering
landing trends	undeveloped	developing	mature	senescent	recovering
relation to maximum production	well below it	approaching it	at or close to it	below it	coming back to it

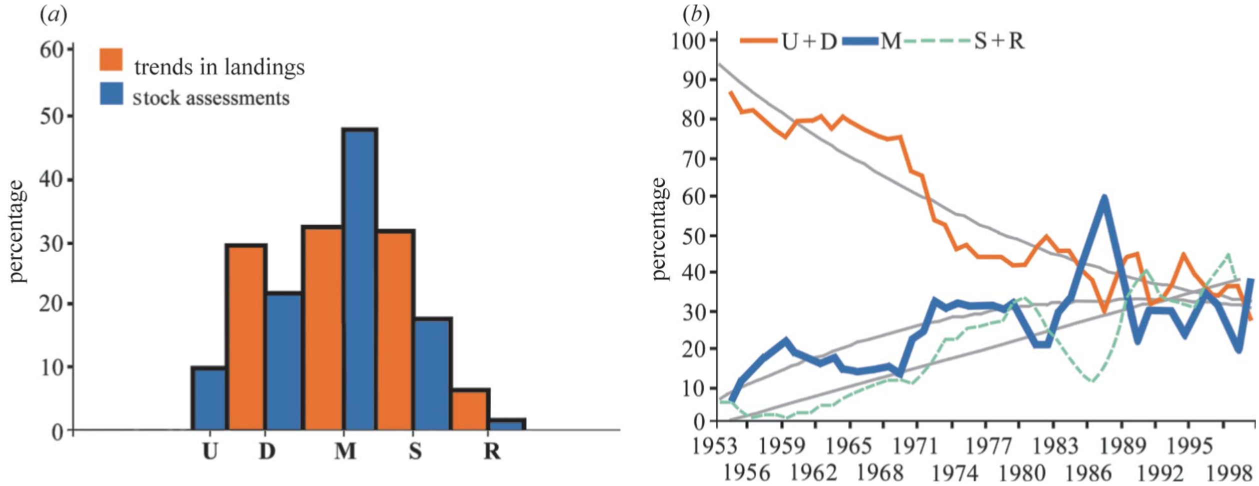

Figure 3. State of the main world fisheries resources in (*a*) 2000 and (*b*) 1952–2000 trend. Abbreviations as in figure 2.

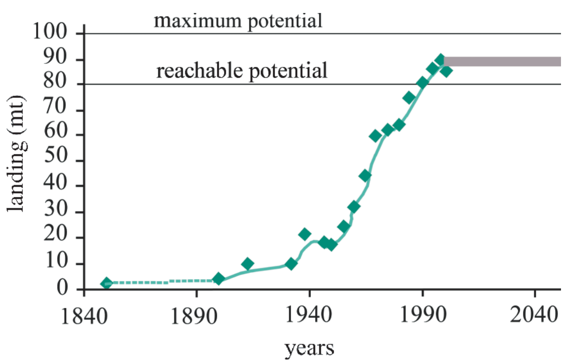

Figure 4. Evolution and projection of marine fisheries supply.

(ii) *by the bottom*—through production of low-value herbivore species, feeding the least endowed people, particularly in the rural areas, decreasing pressure on wild stocks of small pelagic species, facilitating their transformation into human food at affordable prices.

Larkin (1991) underlined that progress in aquaculture followed four main directions: (i) information sharing and application of this knowledge (about nutrition, behaviour, disease, genetics) to production; (ii) increasing demand for seafood because of population increase and adoption of healthier feeding habits; (iii) technological improvement in handling, processing, storage; (iv) reduction in costs of transport with increased speed and reliability. He considered that 'within only a few decades, cultured production of marine and freshwater organisms could exceed that from harvesting of wild stocks' comparing the rapid aquaculture development process to the *'pastoral revolution'*. He predicted:

(i) Stagnation of world wild fish catch and overtaking by aquaculture production before 2020 (the latter not being foreseen in most recent analysis).
(ii) Developments in aquaculture towards better control of reproduction, seaward extension of coastal aquaculture and development of polyculture.
(iii) Growing coordination between capture fisheries and aquaculture administration because of their linkages through the knowledge needed to develop them, their interaction on the market and the threats of land-based pollution on both. This coordination issue is still quasi-nonexistent but is now being considered, for instance, in the General Fisheries Commission for the Mediterranean (GFCM).

Muir & Young (1998) predict that aquaculture will become a global sector, still based on a few key species, progressively evolving towards the production of versatile raw material products, efficient in terms of both productivity and environmental impact. Brummett (2003) confirms that, if it responds to deregulation and to the market as other agro-industries did in the twentieth century, aquaculture will have no problem in meeting the demand challenge. They believe that consumer preferences will shape the sector, that globalization will condition survival, favouring larger units and global low-cost sources such as cage salmon or tilapia and pond catfish or shrimp, and that

Table 2. Situation by 2020 (Delgado *et al.* 2003).
(Apparent errors are caused by rounding of values. Fishmeal equivalent round weight: using a conversion factor of 5.)

scenarios	food fish supply (10^6 t)	capture (10^6 t)	aquaculture (10^6 t)	fish meal (10^6 t) (round weight)	consumption (kg *per capita*)	price difference (%) high-value species	low-value species	fishmeal
present situation (1997)	93	64	29	—	15.7	—	—	—
baseline scenario	130	76	54	39.5	17.1	15	6	18
50% faster aquaculture development rate	144	74	69	—	19.0	9	−12	42
if Chinese production was overestimated	123	69	53	—	16.1	16	6	21
with more efficient use of feeds in aquaculture	131	77	54	—	17.2	14	5	−16
50% slower aquaculture development rate	119	76	41	—	15.7	19	25	0
gradual resource depletion	108	53	55	—	14.2	69	35	134

integration with fisheries will be essential for harmonious co-development of the supply chain, particularly in coastal areas, which offer a large potential for the expansion of aquaculture.

It is usually agreed that the necessary demand,willingness to pay, skills, space, feed resources, etc., are potentially available for this expansion. It is also agreed that challenges are not lacking, related *inter alia* to environmental issues such as habitat modifications or destructions (e.g. mangroves); water and health management; genetic alterations and species introductions; conflicts for use of space and other resources (including with capture fisheries) and release of contaminants. Progress can be expected, as the sub-sector becomes a fully fledged primary production industry. The technology will become more efficient (e.g. in the use of water and feeds), more parsimonious (in the use of space and water and release of contaminants into the ecosystem), shifting from mono- to polyculture. It will complete the range of production systems from capture fisheries, fisheries enhancement and culture-based fisheries to capture-based, extensive and intensive farming systems, integrating with irrigation, agriculture and fisheries for better use of inputs and space.

(i) *Outlook*

The predictions available reflect a strong ‘technological optimism’ (in the sense of Costanza *et al.* 2000) despite the obvious environmental impact and potential scarcity of freshwater, appropriate space and feed supply, particularly for carnivore species. The current aquaculture production (*ca.* 35 mt, one-quarter of the world fishery production) is already higher than the 1995 FAO forecasts, and production is projected to reach *ca.* 70 mt in 2015 (Bruinsma 2003) and 80–90 mt by 2030 (FAO 2000). Other outlooks and the articulation with capture fisheries production will be discussed in § 2d. These predictions are all rather optimistic in that they do not foresee a problem for aquaculture in meeting the future supply–demand gap. Brugère & Ridler (2004), looking at the aquaculture development plans of 18 top-producing countries conclude that the summed national expectations for development match the predictions made from global supply–demand analysis, even though discrepancies are found at regional level.

(d) *Marine supply and food security*

Reported world production of marine capture fisheries has increased from 1.5–2 mt in 1850 (Moiseev 1965) to *ca.* 18 mt before World War II (Chapman 1970), increasing exponentially from 19 to 80 mt between 1950 and the mid-1980s and rising very slowly since then to 85–88 mt (figure 4). Considering that catches reported by China might be overestimated, world marine catches might have indeed stagnated at *ca.* 80 mt, omitting discards (*ca.* 20 mt in the 1980s and 1990s and 10 mt since then) and IUU catches. If the Chinese data are excluded, the marine landings of all other countries have decreased by *ca.* 10% during the 1990s. If Chinese data were corrected as proposed by Watson & Pauly (2001), the total marine harvest from wild stocks would appear stable since the early 1990s (Garcia & de Leiva Moreno 2001). Nevertheless, the annual rate of increase of reported marine catches has decreased from *ca.* 6–9% per year in the late 1950s and early 1960s to almost zero in the first half of the 1990s (see Garcia & Newton

1997), indicating that the maximum possible supply of conventional species has been reached. The straight horizontal thick line drawn on figure 4 beyond the present time includes all species and sources of wild fishes and indicates the total potential supply. Whether or not it will be fully realized will depend on the performance of management and on what will be considered an acceptable impact on the ecosystem in future.

Approximately 70% of marine production is used directly for human food, and marine fisheries play an important role in food security. Part of the world fish production (mainly marine) is reduced to fishmeal and oil used for raising cattle, poultry and fish and is therefore used as human food indirectly. The proportion of the reported marine capture fisheries production that has been used directly for human food has declined from *ca.* 80% in the 1950s and 1960s to *ca.* 65% since the early 1970s (Garcia & de Leiva Moreno 2003). Coastal ecosystems produce more than 90% of the food provided by marine ecosystems. Coral reefs alone produce 10–12% of the fish caught in tropical countries and 20–25% of the fish caught by developing nations. As much as 90% of the animal protein consumed in many Pacific island countries is of marine origin. The reported marine landings used for direct human consumption have steadily increased with time reaching *ca.* 55–57 mt at the end of the 1990s. When China's statistics are excluded, however, the production appears to have been stagnant since the mid-1980s. Considering human population size, the world production of food fish *per capita* appears to have practically doubled since 1950, stabilizing at 9–10 kg of fish *per capita* since the early 1970s. If we exclude China, however, production has declined by 20% (from 11.8 to 9.3) since the mid-1980s.

As marine and freshwater fishes, either wild or cultured, are considered interchangeable food items, the demand for fish is usually jointly analysed. Starting from production and consumption data available in 1965 (*ca.* 50 mt), Giarini *et al.* (1977) correctly predicted that the total world production from all ecosystems and modes of production in 2000, 35 years later, would reach 110–170 mt (actual production: 130 mt, discards excluded). Robinson (1980) predicted that total demand (increasing by 3.3% per year) would outpace total supply, (increasing at 1.1% per year) decreasing *per capita* consumption, particularly in Africa. He did not foresee, however, that aquaculture, mentioned as a possible gap-filling solution, would indeed do so (FAO 2002). He rightly stressed, however, the growing role of the demand for fishmeal (and oils).[8] Westlund (1995) estimated that regional demand for fish would reach *ca.* 100–120 mt by 2010, with the highest consumption in China, Japan, and the rest of Asia and a broadening gap in average consumption between developed and developing countries. She also predicted an increase in demand for fresh, frozen and value-added products as well as a general increase in prices. Ye (1999) estimated for FAO the global demand for seafood in 2015 and 2030 based on extrapolations of trends in consumption and gross domestic product *per capita*. He predicted a doubling of the total demand between by 1995 (95 mt) and 2030 (183 mt) owing to population growth (for 40%) and economic growth (for 60%). The result would be an increase in total demand (of *ca.* 2.1% per year) and demand *per capita* (*ca.* 1.1% per year). Even if *per capita* consumption were to stagnate

Table 3. Trends in SOFIA 2002 for 2010–2030 and comparison with Fish 2020 predictions. (All figures, in mt, have been rounded.)

	2000		2010		2020			2030	
	[a]	w/o China		w/o China		w/o China	Fish 2020[c]		w/o China
marine capture	87	72	84	70	**84**	70	—	84	70
inland capture	9	7	9	7	**9**	7	—	9	7
total capture	95	79	99	83	**103**	87	**120**[d]	107	91
aquaculture	36	11	53	16	**70**	22	41 (**54**) 69	87	27
total production	131	90	152	99	**173**	109	(B)[e]	194	118
food fish production[b]	96	—	123	—	**147**	—	108 (**130**) 144	165	—
percentage used for food	74%	—	81%	—	**85%**	—	(77%)[f]	85%	—
on food use	35	—	29	—	**26**	—	(40)[g]	30	—

[a] Based on latest FAO statistics.
[b] Aquatic animals other than reptiles or mammals, excluding quantities reduced in fishmeal and oil.
[c] Fish 2020: most likely scenario (bold, in brackets) together with best and worst cases if available.
[d] Calculated by the authors from total production minus aquaculture.
[e] Calculated by the authors adding food fish to fishmeal production.
[f] Calculated by the authors comparing food and non-food use.
[g] Calculated by the authors multiplying fishmeal production forecasts by a factor of 5.

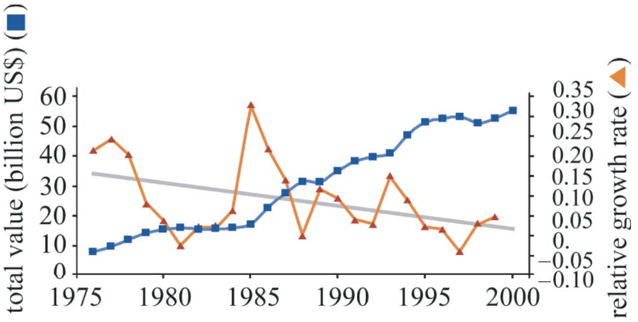

Figure 5. Total value of exports (all sources) and annual relative growth rate (data FAO-FIDI).

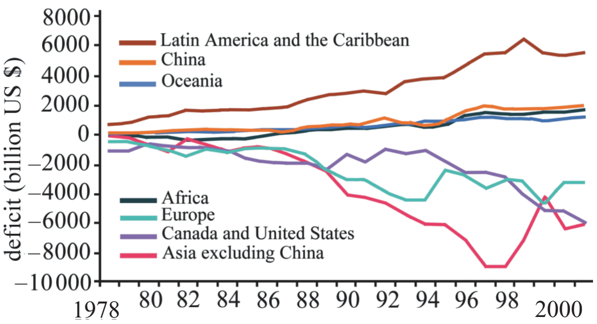

Figure 6. Trade surplus/deficit by region (1976–2000) (data from FAO-FIDI).

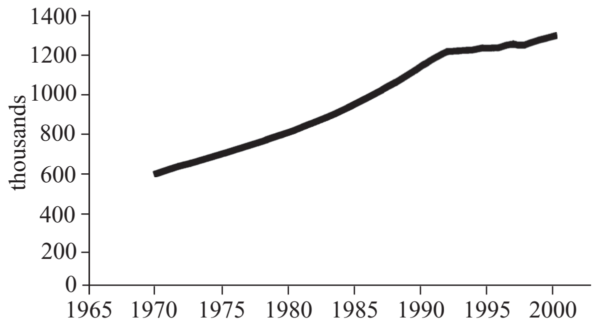

Figure 7. Number of decked fishing vessels in the world fleet. (Source: Food and Agriculture Organization of the United Nations.)

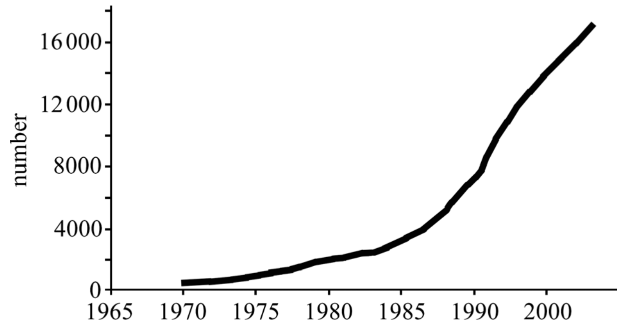

Figure 8. China's vessels over 100 GT.

instead at the 1995 level, 127 mt would still be required by 2030. Wild fish production stagnating at *ca.* 80–100 mt, the results point to a dramatic increase in pressure on aquaculture to fill the supply gap.

Delgado *et al.* (2003) modelled future supplies, demand, prices and trade of food fish up to 2030 in the broader context of evolving world food market.[9] They simulated a moderately conservative baseline[10] scenario, basically extrapolating recent trends with decreasing rates (table 2).[11]

They also considered alternative scenarios involving: faster or slower aquaculture expansion; lower production than expected in China; an increase in aquaculture feeds use and a so-called ecological 'collapse', a worst-case scenario with a decrease in capture fisheries production of 1% per year. The forecast for total supply ranges from 108 mt in the 'catastrophic' scenario to 144 mt for the most optimistic one with a baseline (most probable) value of 130 mt. The baseline scenario forecasts modest fish price increases (6–15%) by 2020. The study foresees a significant increase in fishmeal and oils value in most scenarios owing to fast developing aquaculture out-competing other sectors in the demand for a luxury feed item for high-value carnivores. The 'collapse' scenario—indeed a progressive erosion of the global resource base—leads to a 17% decrease in wild fish production, economically compensated by price adjustments. In general, *per capita* consumption is seen to increase in the developing world. The authors predict that, despite globalization and consequent tariff reductions on unprocessed products, a high tariff on processed products and non-tariff barriers will be maintained or raised to block imports. They stress that this could have the collateral effect of displacing small-scale fisheries of the developing world through economies of scale.

FAO produces every two years the only recurrent fisheries outlooks available for its Committee on Fisheries. Since 1996, these have been published in The State of World Fisheries and Aquaculture (SOFIA; FAO 1997, 1999, 2000, 2002). SOFIA 2002 contains a forecast for fisheries production until 2030 partly based on the work carried out by Ye (1999). It forecasts that, over the next 30 years, the demand for seafood and its *per capita* consumption will continue to increase at decreasing rates. Total capture fisheries production will stagnate around the levels observed during the last decades (90–95 mt, of which 80–85 mt from marine capture fisheries). Total production will increase to *ca.* 190 mt, compared with the 130 mt of the early 2000s. Aquaculture production will continue to grow more slowly, from the present 36 mt to *ca.* 83 mt. In developed countries, consumption patterns will increase demands and imports of high-cost/high-value species from the developing world. In developing countries, high-cost/high-value species will be exported while low-cost/low-value species will be imported for local human food. Latin America will become the largest capture fisheries producer and leading net exporter, while Europe, USA, Africa and Japan will increase their imports. The Near East will shift from net importer to net exporter. South Asia will shift from net exporter to net importer. Europe's and Japan's capture production will continue to stagnate. The USA's demand will further shift to high-value species but its production will stagnate. The increase in demand related to population growth and economic development will be met by increased aquaculture production.

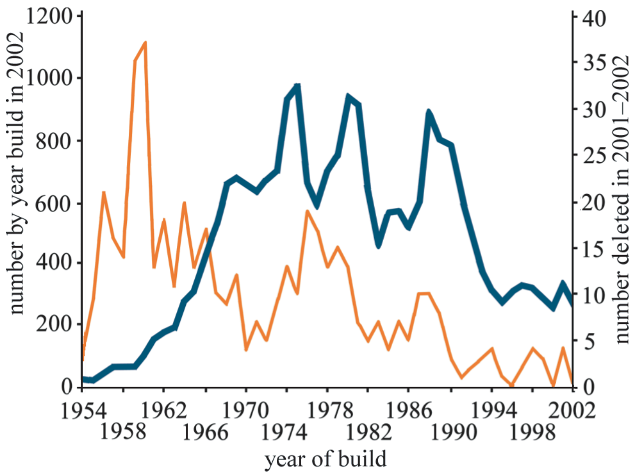

Figure 9. Number of vessels in 2002 by age of build (thick line) and deletions in 2001–2002 (thin line).

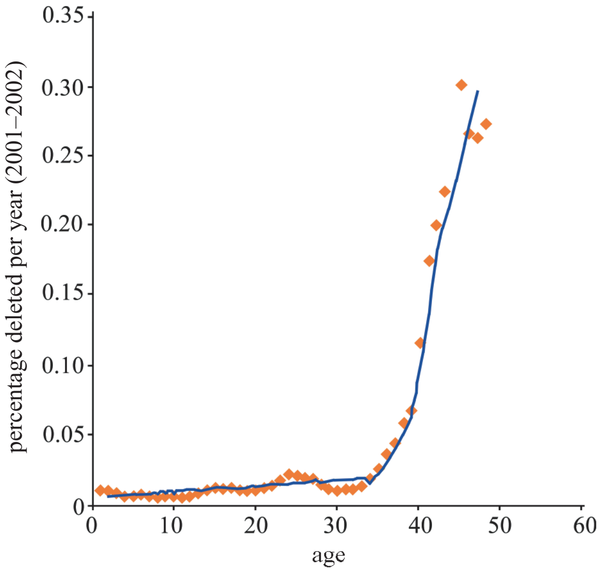

Figure 10. Rate of deletion of vessels against age.

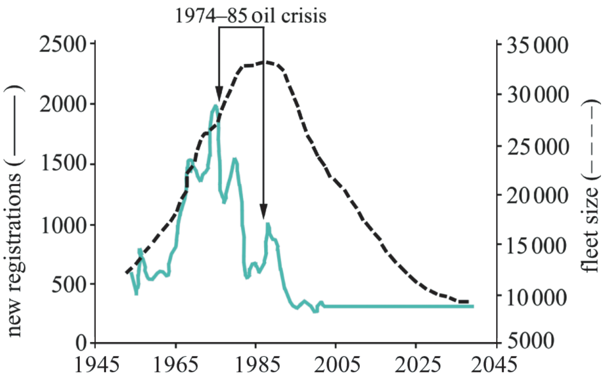

Figure 11. Estimated recruitment and total registered fleet size (vessels over 100 t).

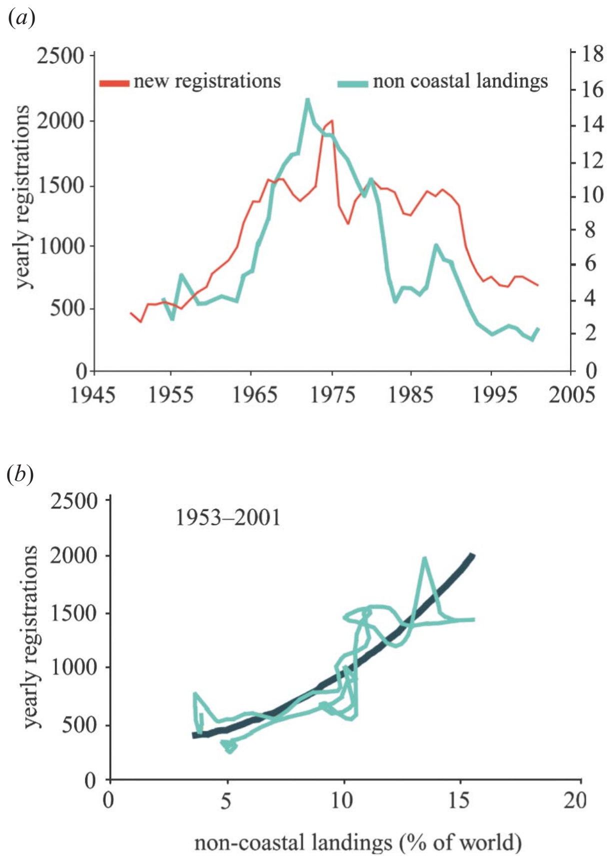

Figure 12. Relation between new registrations and reported distant-water fishery landings. (*a*) Time series; (*b*) correlation.

(i) *Outlook*

Table 3 demonstrates that the forecast of SOFIA 2002 falls within the range of forecasts made in Fish 2020 (Delgado *et al.* 2003). The SOFIA production figures (total, human consumption and aquaculture) are on the high end of the Fish 2020 forecasts but are more pessimistic for capture fisheries production.

These predictions, conditioned by the limited potential of wild conventional resources, the assumed human population growth and the progress of aquaculture, are still to be tested. There seems to be agreement, however, that:

(i) Production will stagnate in capture fisheries and more than double in aquaculture, meeting the demand resulting from population growth and economic growth and containing price increases.
(ii) Global *per capita* consumption from marine resources will decrease, simply because of human population continued growth and development. Wild fish prices may however remain rather stable. However, considering the poor state of marine resources, the growing degradation of the environment and the impact of climate change (e.g. in coral reef fisheries, destroyed by coral bleaching) the 'worst case scenario' elaborated by Delgado *et al.* (2003), assuming a 1% decrease of the resources per year, may be too optimistic.
(iii) Asia will become a net importer and Latin America a leading exporter.
(iv) Rich countries, already net importers, will increase their trade deficit.
(v) A strong market for fishmeal and oil will develop for aquaculture, affecting marine capture fisheries for the corresponding species.

(e) *International trade*

Approximately 50% of the total world fish harvest is internationally traded. Total fish trade from all sources (measured by total exports) increased from 2.5–3.4 billion US$ in 1969–71 to *ca*. 55 billion US$ in 2000 (an increase from *ca*. 5% to 10% of total agricultural trade). The majority of this trade is from marine capture fisheries, the export value of which was worth more than 40 billion US$ in 1999. Since 1976, however, the relative annual rate of growth in trade has been decreasing and is approaching zero (figure 5).

This would indicate that, after about three decades of adjustments reflecting the post independence economic development process, the progressive implementation of the new Law of the Sea, and the discovery and exploitation of practically all conventional fish resources, world fish trade would reach a period of stabilization[12] (zero growth) possibly c. 2005–2010. This also seems to indicate that, for the moment, the large increase in aquaculture production of the last decade has mainly been consumed locally. However, if as foreseen by Delgado *et al.* (2003) and in SOFIA (FAO 2002), India, Latin America and Africa become significant exporters of aquaculture products during the next two decades, we might see a new global increase in trade in the future.

This global picture masks variations between regions. The global contribution of the developing world to fish trade has increased regularly since the 1970s, from 32% in 1969–1971 (Garcia & Newton 1997) to 43% in 1990 and just over 50% in 2000 and 2001. Garcia and Newton stressed that the sustainability of the global fishery system was at stake in a 'suicidal' loop, involving growing removals and exports from the dwindling developing countries' fish resources to supply the overfished developed world, while simultaneously dumping on that developing world the excess capacity of the developed one, exporting overfishing to the main source of the global trade system. The future picture in this respect depends on the evolution of capacity in the developed world and the fate of the removed excess, the amount of which is well beyond the residual absorbing capacity (if any) left in the developing world.

The data on the trade deficit or surplus since 1976 (figure 6), when the extension of EEZs became generalized, show that: (i) Latin America is rapidly growing as a major net exporter; (ii) Exports from China, Africa and Oceania are developing more slowly, (iii) Canada, United States and Europe are becoming the main net importers; (iv) Asia (excluding China) is the main net importer but its situation may be reversing since 1995.

(i) *Outlook*

The progressively greater liberalization of the market may add significant pressure on developing countries' resources, particularly high-value fish for export. As this is apparently compensated by them through increasing imports of low-value fish, the pressure exerted by consumers, rich or poor, will spread to all types of resources. Exports from developing countries need to be compensated by production of low-value aquaculture fish to maintain local food security. A global reduction of subsidies to the catching sector would increase the advantage of the developing world as well as their exports. However, simulations indicate a growing conflict between internal and international demand (i.e. between local food security and export earnings) as populations grow in developing countries, particularly those in the low- to medium-income ones, where demographic growth will be higher (Delgado *et al.* 2003).

(f) *Fishing technology*

Fishing and processing technology have underpinned the fantastic boom in fisheries between 1950 and 1970: freezing; diesel engines; synthetic fibres; acoustic devices; hydraulic power; skinning, filleting, dressing and filling machines; fishmeal machines; air transportation for high-priced goods or bulk shipment (e.g. for fishmeal) (Chapman 1970). The past three decades have seen the continuous improvement of navigation, acoustic and fish location devices (including computers, spotter planes and helicopters, remote sensing, automated sea mapping) and processing methods for new products (e.g. fish protein extracts such as surimi). How much of this had been foreseen?

We have not found many futuristic predictions of fishing technology. Forty years ago, Alverson & Wilimovsky (1964) provided a fictional picture of future (high-tech) fishing, much of which has still not been achieved even today and could well be taken as a possible future for the third millennium fisheries. Some of their fiction has become reality: for example, remote measurement of ocean temperature and other parameters; electronic single-fish detection and identification; pop-up, free-floating devices, transmitting their data to satellites (e.g. archival fish tags) and sound, bubbles and electrical barriers and irradiation to preserve food items. Other predictions have not materialized to any extent, at least to our knowledge and may still remain at the horizon of today's engineering and may dramatically increase fishing capacity: fish attraction by sounds; fish detection 'drones', networks of unmanned fish-detecting buoys connected to satellites; sea-bottom nuclear reactors to generate upwellings; chemical detectors of fish presence; attraction and herding of fishes through olfactory stimuli.

In 1964, the *New Scientist* magazine (cited by Larkin 1991) published a series of papers predicting that, by 1984, 20 years later, fisheries would undergo a number of 'revolutions' including: (i) progress in fish rearing and species transplantation; (ii) mid-water trawling technology; (iii) discovery of new food resources in squids (Cephalopods of the order Theutida), Antarctic krill (*Euphausia superba*) and redfish (*Sebastes* spp.) stocks; (iv) intensive development of coastal resorts and sea sports; (v) United Nations' ownership of the seafloor and (vi) increased role of scientific advice for governments. The two major unknown factors conditioning the future were identified as the capacity to reduce pollution and to ensure sustainability of wildlife in the absence of reserves. Retrospectively, one can only be impressed. The predictions were largely correct. Land-based pollution is still a major unknown (as stressed by the United Nations Conference on Environment and Development (UNCED) in 1992 and the World Summit on Sustainable Development in 2002), and the role of marine reserves or protected areas is now a central issue in fisheries management. The same series of papers rightly predicted global warming, use of trained porpoises for human leisure and more accurate long-term weather forecasting using satellites and buoys. The only failed prediction was that humans would develop control over the genesis of hurricanes.

Implicitly assuming that present developments were going to spread, Hotta (2000) forecasts an 'artificialization' of the coastal environment between now and 2010 with growing use of artificial reefs, enhancement techniques, ranching and extensive mariculture. The main problems will remain overcapacity, overfishing, over-crowded small-scale fisheries and increased social unrest. Increased pollution will affect fish quality and productivity. Aquaculture, emerging as a primary resources consumer, becomes a potential environmental threat, with poor public image.[13] The possibility to cultivate directly seafood tissue (as opposed to organisms) is contemplated, despite the technological challenge and the probable market resistance (Kearney *et al.* 2002).

(i) *Outlook*[14]

Many technological developments are still in prospect with diverse impacts on the sector. As they are usually 'imported' from other sectors, they are not too difficult to identify, even though the likelihood and timing of their adoption can only be guessed. Without any priority ranking, potential developments include:

(i) more efficient use of fishmeal and oils;
(ii) better species/sex/size selectivity using hormones or Pavlovian reflexes (over short distances) and sounds (over longer distances);
(iii) biodegradable fishing equipment;
(iv) habitat mapping (acoustics) for better targeted fishing and habitat protection;
(v) better set fishing equipment for reduced bottom impact, including offshore fishing platforms using attracting stimuli and devices;
(vi) autonomous fish/plankton detection devices to improve assessment and forecasts;
(vii) vessel location and monitoring systems;
(viii) more effective and automated information processing;
(ix) generalization of the use of DNA tracking for fishery product identification (e.g. shark fins);
(x) low-impact aquaculture;
(xi) better decontamination processes to mitigate the effect of growing pollution;[15]
(xii) fertilization of the iron-limited oceans to improve primary productivity;
(xiii) automatic fish sorting and measuring devices (e.g. through image processing);
(xiv) automated freezing at a very early stage of fish processing;
(xv) development of methods to reduce waste of water-soluble proteins in surimi production;
(xvi) use of archival tags to monitor the delivery chain;
(xvii) production of pharmaceuticals from marine animals, etc.

Small-scale fisheries will be protected as long as deemed necessary to maintain populations in rural areas. Boat quality and safety on board can still be notably increased, but the potential for increased capacity through adoption of new and low-cost technology is extremely high. Fishing villages can be modernized and equipped to ensure the product quality required for high-value markets. Small-scale fisheries can be integrated vertically with industrial processing and marketing, as well as with aquaculture (e.g. for ranching). Last, but not least, as subsidies are suppressed and coastal countries develop their own capacity to fish in their EEZs and in the adjacent high sea, long-range fleets are likely to disappear. The last to disappear are likely to be those targeting highly variable pelagic resources for which an alternative to large-scale rotational exploitation may not be easy to find. A note of warning, however: globalization has already led to extinction of large sections of the artisanal segments of many production sectors. In a fisheries' *Market World* (see § 3), the same causes may well have the same effects.

(g) *The large vessels fleet*

Economists and biologists are still trying to define fishing capacity and to measure its excess (Cunningham & Gréboval 2001; Pascoe & Gréboval 2003). Usually, all segments of the fishery sector have some operational justification for their own capacity and expect that any excess will be identified and removed elsewhere. Conventional measures, as well as limited entry, have failed to reduce it and use rights are strongly advocated for the purpose. Excess capacity also seems to exacerbate reflagging and IUU fishing. However, the global economic forces have had a major and little known impact on the world fleet's size. Towards the end of the 1990s, according to FAO statistics, the world fleet comprised approximately 4.1 million vessels, of which 1.3 million were decked and 2.8 million undecked, of which 65% were unpowered, showing the importance of small-scale fisheries. Figure 7 shows the increasing trend in numbers of decked fishing vessels of all sizes since 1970 and the slower growth during the 1990s.

Although FAO provides some global fleet statistics, there is no comprehensive database of individual vessels of the world. The Lloyds database contains data on vessels over 100 gross tons (GT) (or *ca.* 24 m overall length) and may give indications of historical trends. It is not comprehensive and in 1999 held only 80% of the vessels registered in the FAO database (Smith 1999). It also contains only approximately 400 Chinese vessels, while the fleet, which has grown rapidly in the 1970s and particularly in the 1990s, contains more than 15 000 vessels (figure 8). However, Smith considers that the trends observed in the database are representative of those in the whole fleet. Its coverage has improved with time,[16] and the more recent data are closer to reality. The bulk of the present fleet has been built essentially between 1970 and 1990, and the comparison of the age structure of the registered fleet between 2001 and 2002 shows that the number of 'deletions', as expected, increase with age (figure 9) and that the annual rate of deletion (a 'mortality rate' of vessels) is low from 1 to 35 years, increasing only slowly with age and increasing very rapidly after 40 years (figure 10).

To rationalize the data, the functions fitting the data before and after age 35 were calculated using simple linear regressions, and values for the intermediate ages (36–39) were interpolated. Applying the rationalized deletion rates to the age structure of the fleet in 2001, the numbers-at-age were calculated back for as many years as ages are available in the 2001 dataset, yielding both a calculated number of

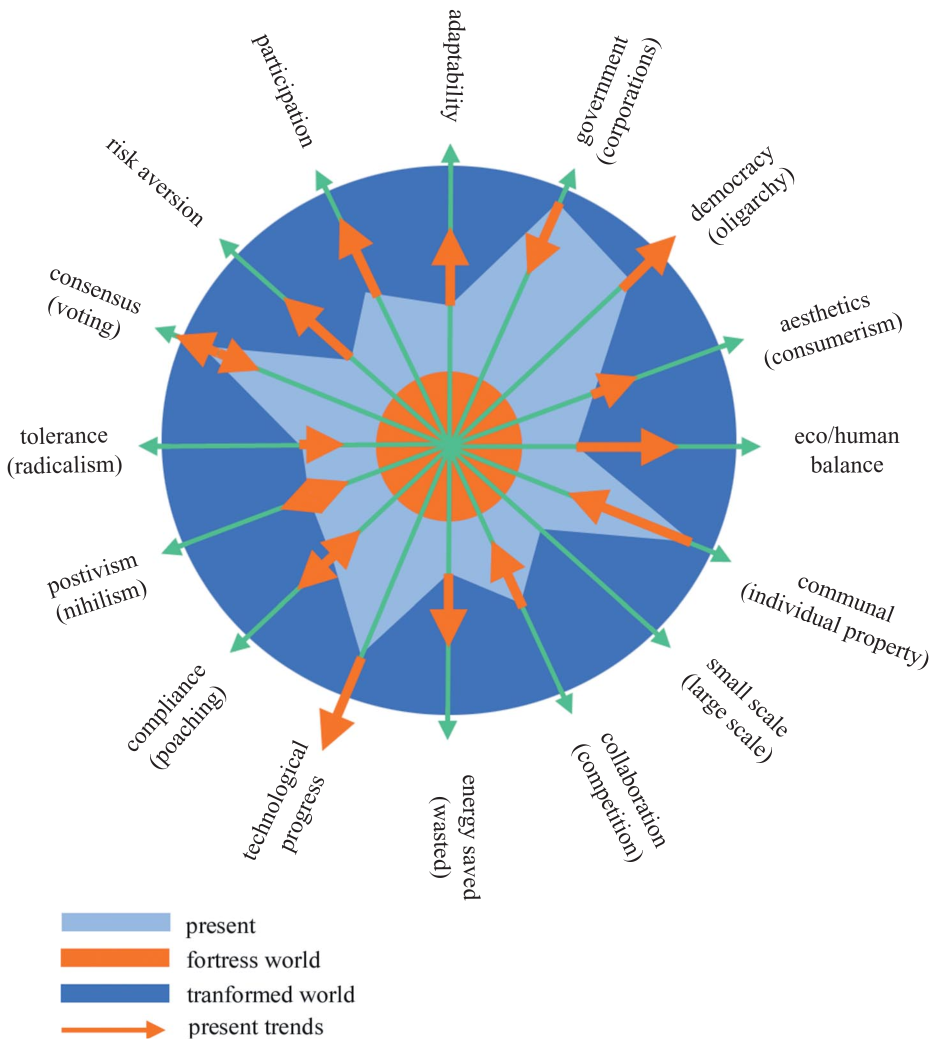

Figure 13. Main characteristics of the present and future scenarios (see § 4).

new entrants (e.g. 'recruitment' at age 0) and total fleet size for the period 1953–2001. Assuming deletion rates at age remain valid in the future and the new registrations stabilize at 300 vessels per year (as observed during the past few years), the total registered fleet has been projected for the period 2002–2040 (figure 11).

The registrations appear to have rapidly increased from *ca*. 500 per year in the 1950s to *ca*. 2000 by the mid-1970s, rapidly decreasing to *ca*. 300 currently. The boom corresponds to the geographical expansion phase of the fisheries from the 1960s to the mid-1970s. The sharp decline between 1975 and 1985 appears to coincide both with the well-known oil crisis (and oil price increase), as well as with the main phase of unilateral extension of EEZs by coastal states. The 1990s decrease coincides with the demise of the long-range fishing from the former USSR fleets. These coincidences tend to support the idea that these numbers reflect, to a large extent, the boom-and-bust of long-distance fishing, an interpretation reinforced by the good relation between the estimated 'recruitment' and the landings of distant water fishing[17] (figure 12). Assuming a constant recruitment of 300 vessels per year, this fleet would decrease by more than 50% between now and 2030.

(i) *Outlook*

The likely evolution of the large-scale fleet (more than100 t) given above must be considered with caution. However, the trends in the database are considered representative of changes in the whole fleet (Smith 1999). More recently, this growth has been halted by stricter licensing control and the introduction of vessel-scrapping schemes. Despite these reservations, the results indicate that the three-decades-long boom of the large vessel fleet, prompted successively by exploration and EEZ extension, is over. The potential increase in oil prices will most probably reduce that fleet further.

During that period, however, the coastal countries' fleets grew in numbers and vessel fishing power, developing a fishing capacity equal—if not superior—to that of the foreign fleets that they progressively replaced. The overall continuing degradation of the resources illustrated in the earlier sections indicates that the overall fishing capacity is still extremely high. Whether and how fast capacity will decrease in future depends on progress made in governance (see § 2h). Considering the international agreement on the need for capacity reduction, e.g. stimulated by the FAO International Plan of Action (IPOA-Capacity) and global efforts to eliminate subsidies, it is likely that investments in fleet building will decrease substantially (as simulated in figure 10). What is far from clear is whether the technology-driven efficiency gains will be sufficiently controlled to keep fishing mortality down. General adoption of fishing rights may be effective in that respect at the cost of transitional exclusion (Garcia & Boncoeur 2004).

(h) *Governance*

Understanding the causes of past problems and their present evolution is useful when looking into the future. As mentioned in § 1, numerous authors have written about causes of the relative failure of fisheries management[18] and they will not be repeated here. These have been detected decades ago and attempts are being made to correct them through: (i) various forms of user rights; (ii) improved frameworks (e.g. UNCED, WSSD and FAO Code of Conduct); (iii) reduced subsidies; (iv) reinforced role of Flag and Port States; (v) strengthening of management fishery bodies; (vi) improved science; improved participation, transparency and public awareness; (vii) ecolabelling; (viii) capacity building; and (ix) precautionary and ecosystem approaches to fisheries. Binding and voluntary international instruments have definitely improved the arsenal of rules and regulations available to the states and the sector.[19] Too little progress has been made, however, in the area of control of the access to fishing, limitations and reduction of fishing capacity and establishment of explicit user rights (Garcia & Boncoeur 2004). Very little has been achieved in terms of integration of fisheries governance into coastal area management, the latter progressing rather slowly. The process of extension of EEZs is being completed, with obvious difficulties in the remaining and disputed areas such as the semi-enclosed Mediterranean Sea. Attempts to gain coastal State jurisdiction beyond 200 miles seems to be in abeyance, perhaps waiting for assessment of progress in relation to IUU fishing, transboundary stocks. RFMOs are being held to greater accountability by the international community (FAO 2002). The process of sub-regionalization of the RFMOs, aimed at higher relevance and performance is not always supported by adequate resources and coordination and functional gaps exist where there is no RFMO (e.g. in the northern Indian Ocean) or the existing one is not effective (e.g. Asia–Pacific Fisheries Commission in Southeast Asia). In several bodies, members have refused to shift from an advisory/coordinating role to a management one, illustrating a lack of political will. With some exceptions, regional fishery bodies in the developing world are less functional today than they were 10 or 20 years ago. The technical and financial assistance provided by donors during those times dried up in the 1990s and was not replaced, as expected, by higher financial commitments from member states and more effective delegation of powers, and the trained human resources are fading away. As a consequence, but with some exceptions, for example in the North Atlantic, South Pacific and Southeast Atlantic, fishery bodies do not seem to be on their way to meet expectations.

In the early 1970s, Larkin & Wilimovsky (1973) pessimistically predicted that 'despite efforts to intervene, there will be little sustained success and fisheries will proceed more or less as if they were not managed' and their detailed forecasts represent a rather accurate account of fisheries governance during the three following decades. Garcia (1992) correctly outlined the probable developments of the following decade regarding overcapacity, overfishing, conflicts, non-consumptive uses, allocation, environmental degradation, subsidies, discards, statistics, high-sea and deep-sea resources, RFMOs, endangered species, creeping jurisdiction, public opinion and precautionary approach, most of which had been previously singled out in the literature. Garcia & Grainger (1997) did not agree that the marine capture fisheries could be considered a 'sunset industry', considering its essential role as a source of food and livelihood and relatively low societal risk it represents when objectively compared to chemical pollution, ozone depletion or degradation of freshwater resources. They foresaw two possible developments in the absence of significant progress in governance: (i) *acute crises*, with progressively more frequent occurrences of brutal and long-lasting resources collapses; or (ii) a *chronic degenerative trend* with surreptitious degradation of the resources and socio-economic conditions. The present global situation, as during the past five decades, can indeed be characterized as a chronic degenerative trend with occasional, localized acute crises.

(i) *Outlook*

Progress made during the past decade in the institutional and normative framework of fisheries seems to lead to optimistic outlooks. In his fictitious, retroactive and prospective review of world marine fisheries for the period 1975–2025, Beckett (1998) expresses his faith in the full implementation of available instruments and significant progress in all the deficient areas referred to above. A similar optimistic vision transpires also from the analysis by Parsons & Becket (1998) and Rosenberg (1998). The key unknown for the future is in the degree to which industry leaders and policymakers will indeed implement the wealth of high-level commitments mobilized in the last decade of the twentieth century. While this may be locally possible, it seems difficult to generalize, considering the past performance of fisheries management and the lack of implementation capacity in many areas.

Science has been a major component of fisheries governance, and the phenomenal progress in scientific understanding accomplished during the past 50 years has significantly improved the elaboration of management advice. In spite of this, management performance has been dismal, and the levels of uncertainty are still very high. UNCED and WSSD have highlighted the need for more research to establish sustainability indicators for fisheries and test the protocols for precautionary and ecosystem approach to fisheries. In a market-driven economy, with increased privatization, fishery research can shift rapidly from mode 1, largely fundamental and publicly funded, to mode 2, essentially problem-solving and privately funded.[20] By design, the latter may optimize private use at the expense of public interest (Nelson 1998). The growing dependence on private funding and the confusion between science and advocacy threaten the independence of science and its credibility as a support of improved governance in front of global societal risks (Jasanoff 1994). The increasing recourse to litigation to rebuff scientifically backed management decisions, at least in some countries, also represents a preoccupation.[21]

Table 4. Correspondence between the various future world scenarios.

	business as usual		worst case		best case	
Hammond (1998)	market world		fortress world		transformed world	
Gallopin (2002)	conventional worlds		barbarization		great transitions	
	reference world	policyreform	fortress world	breakdown world	eco-communalism	new sustainability
UNEP (2002)	market first	policy first	security first		sustainability first	

3. THE CRYSTAL BALL CHALLENGE

The difficulty in forecasting the future in general and that of fisheries in particular was stressed in § 1. One way out of this confounding analytical problem, used to address environment and development problems since the 1970s (Gallopin 2002), is to elaborate scenarios to describe the most likely pathways for change with their major events, dynamics and outcome. Future fisheries scenarios attract policymakers' attention on possible alternative courses of events and on possible bifurcations and low-probability 'surprises', at which the future may change course. Scenarios may also help clarify and articulate apparently conflicting views on the future. They also provide an opportunity to complement or challenge conventional thinking and open ground for debate.

The elaboration of credible future scenarios for fisheries requires a detailed characterization of the past and present of the sector and the identification and articulation of key issues. Section 2 contains substantial material in this respect. It also requires identification of the main forces driving the probable changes with their trends and uncertainties. The fishery sector, however, represents a tiny part of the global society, and its economy and possible trajectories will be heavily conditioned by the evolution of its ecological, social and economic contexts, at local to global levels. The outlining of fisheries scenarios therefore requires a visionary representation of the possible futures of the world within which fisheries will operate. It also requires that the analyst explain clearly the type of contextual world in which his prediction fits.

(a) *World scenarios*

Several scenarios for the world's future, reflecting a 'Business as Usual' scenario as well as 'best cases' and 'worst cases', have recently been proposed for the twenty-first century, all inspired from the work of the Global Scenarios Group (Hammond 1998; Gallopin 2002; UNEP 2003) that could be used to outline the possible contexts within which future fisheries could evolve. These scenarios are displayed in table 4 and are examined further in the following sections.[22]

(i) *Business as usual: a market world*

In the 'Business as Usual' scenario, present trends and forces are smoothly extrapolated perhaps with levelling off rates of change. Driven by market globalization, this scenario is referred to as *Market World* or *Conventional World*. It may have two variants: (i) *Reference World* or *Market First* scenarios, totally market-driven, in which, as in the last decades, too little is done too late to reach sustainability as short-term interests dominate processes; and (ii) *Policy Reform World* or *Policy First* scenarios, triggered by public consensus and political will, in which exceptional governmental efforts lead to improved sustainability through democracy and freedom, unprecedented social and economic advances, and improved resources and environment without major changes, however, in fundamental values and dominant paradigm. The key phrases are: free and deregulated fish trade, elimination of tariffs, privatization of resources, foreign investment, export-oriented developments, private sector partnerships, industrial growth, vertical and horizontal integration, emergence of large multinational corporations, information technology and innovation.

The optimists hold that decisive action would be facilitated by reduced population growth and increased economic growth (in *Policy First* and *Policy Reform* variants). The transition to better sustainability would be facilitated by awareness of tangible effects of the looming crisis and a significant increase in implementation of the international fishery conventions, arrangements and legal instruments agreed during the past two decades. The sceptics stress that, in the poorest countries and communities lacking the preconditions to benefit from the market economy, poverty, unemployment, corruption and violence would persist or increase as would generally, the gap between poor and rich, while the disconnection between people and decision-makers would increase. In centralized economies, reforms would remain slow or incomplete, and trade barriers would persist. The low priority accorded to improved governance and human capital development would lead to depressed levels of education and health. Resilience of socio-economic and ecological systems would decrease as resources are depleted, habitats are degraded and social cohesion weakens. The risk of flaring of racial or religious conflicts increases. Eventually, this scenario leads to a global crisis.

The need to ensure economic growth, as well as the convergence between the development and environmental conservation requirements, is a formidable challenge unlikely to be met in the absence of a fundamental change in values and institutions. Under a Business as Usual scenario, continuous readjustments will be needed in the attempt to slow down resources degradation and mitigate the effects of growing inequity. However, as time elapses, the situation worsens, available solutions become scarcer, and the necessity and cost of the transition to better scenarios increase (Gallopin 2002).

(ii) *Worst case scenario*

In the worst case scenario, characterized by failure and collapse of democratic governance, ethical standards and societal objectives, the system is maintained through a 'feudal' system of governance by a dictatorial minority owning 'islands of well-being in an ocean of chaos'. Referred to as a *Fortress World* or *Barbarization*, this scenario may have two variants: (i) one leading to total chaos and anarchy (*Breakdown World*) and (ii) one under which chaos is partly controlled by a feudal system of governance (*Fortress World* or *Security First*).

The key phrases are: highly protected or illegal trade, rising tariffs and non-tariff barriers, inequity in resources allocation, rising illegal fishing and crime, export-oriented developments, decreased food-security for the poorest, private alliances, priority on industrial growth and integration with emergence of large multinational corporations.

This scenario would emerge from ascending market forces in a context in which governance is incapable of managing the change and mitigating its negative consequences on people and the environment. It develops out of the economic divide and conflict between individuals, communities and countries about scarcer resources depleted in a policy-deficient *Market World*. It threatens millions of the most vulnerable livelihoods. Civil disobedience and nihilist tendencies (IUU, destructive fishing, intolerance and radicalism) grow in young generations out of frustration about lack of opportunity and growing poverty. Unabated pollution affects productivity and seafood quality, life conditions, health and climate. Anarchy prevails but the resulting chaos may be partly controlled by feudal types of governance (that still exist!). Global economic and infrastructure development, technological progress and expenditures on social security or education are stalled, while expenses on security increase drastically. Less resilient systems collapse. Aquaculture products are essentially luxury food items contributing little to food security. The poorest regions (e.g. Africa south of the Sahara and South Asia) suffer most, hit by AIDS, climate-change-driven droughts and resulting famines. As in chaos, entropy is close to maximal; equity will prevail as most people will be equally poor. The emergence of a feudal organization would reduce entropy, materializing inequity between 'islands' of militarily protected well-being and 'oceans' of distress. This scenario may therefore be very stable and, in the absence of external interventions, may require a long phase of reorganization before a new and better pattern can emerge.

(iii) *Best case scenario*

In a best case scenario, possibly prompted by a global crisis,[23] the human sense of ingenuity and compassion leads to a better and more equitable life for most, and all the conceptual objectives underpinning today's ideal vision of sustainable development are achieved. Referred to as a *Transformed World* or *Sustainability First* scenario, it is seen as a scenario of *Great Transitions* with two variants: one in which sustainability is achieved through 'regression' to simpler village life with low-energy consumption (*Eco-communalism*) and one compatible with modern urban development and technological progress (*New Sustainability)*. The *Back to the Future* strategy proposed by Pitcher (1996) and Pitcher & Pauly (1998) would fit under this scenario.

The key phrases are: decentralization, ecosystem and human well-being, participation, collaboration, equity, communities, egalitarianism, self-sufficiency, fair trade, flexibility, adaptation, global ethics, conflict resolution and negotiation. People are environmentally conscious. Rich people modify their consumption patterns, allowing poor communities to improve food security and resources to recover. Education, leisure and spiritual pursuit are valuable incentives. Ethical codes require wise resource use. International agreements (e.g. for shared and straddling resources) resolve the resource allocation issues. Discards are banned. Critical habitats are protected. Large polluting companies agree to pay for and mitigate damage and to adopt longer-term horizons for decision-making. Energy consumption and greenhouse gases are drastically reduced. Market forces are mitigated by consensual social and environmental goals. Income tax reductions boost the economy, allowing for a renaissance, positive welfare reforms, reduced poverty, improved health, an increased role for citizen groups and religious congregations. This evolution is boosted by an information revolution and internet development, accompanied by greening of the private sector, improved corporate ethics and deeper involvement of philanthropic foundations. It allows for the emergence of alternative livelihoods to fishing for coastal communities.

Although this scenario would improve harvest quality and value, as well as the revenues and profits of those fishers remaining in business, it is likely to decrease total catches, increase prices and reduce accessibility to seafood for the poor unless total population declines rapidly, developed economies collapse, or aquaculture focuses on low value species, all rather unlikely.

(b) *Driving forces*

The future of fisheries will be conditioned by numerous interconnected driving forces and triggering factors affecting their ecological, economic, social and political development field, raising societal conscience about the risk for future generations in terms of poverty, mass migration, famine and epidemics. *Ecological factors* include environmental degradation, resource collapses or global climate changes. *Economic factors* include a long-predicted collapse of the stock market[24] or a new oil price shock[25] or both. *Social factors* include an unacceptable gap between poor and rich, major social dislocations provoked by major industries' relocation, emergence of instant and global awareness about inequity (e.g. through the internet), frustration leading to radicalization of ethnic and religious discourses with resulting conflicts and dislocations. The response to one set of triggering factors depends to some extent on the situation of the others and the final result depends on degree of preparadness, contingency plans, emergency assistance and effectiveness of international collaboration.

The *Market World* is spreading in the developed economies of the western world and beyond through globalization of the market economy. The evolution of the fishery sector, from a *Market World* to a slightly better, ideal or worst situation, will take place in broader contexts characterized by environmental, techno-economic and socio-cultural factors including institutional and ethical ones, as well as driving forces that will condition the viable options and their outcome. Consideration of possible future scenarios becomes an arbitrary exercise, simply conditioned by one's optimism or pessimism unless the trends in the main driving forces are carefully and objectively considered. The main driving forces include global economic development patterns, population growth and the state of the environment. Other forces include public awareness, wars, information, epidemics (HIV-AIDS), energy prices and global ethics. The main ones are briefly elaborated below drawing significantly from Entz *et al.* (2000), Gallopin (2002); Glenn & Gordon (2002) and UNEP (2003) with emphasis added regarding their effects on fisheries.

Global economic development patterns affect the future of all economic sectors. The progressive globalization of the market economy has affected fisheries[26] and will continue to do so (UN Atlas of the Ocean 2003).[27] Present trends are towards more service-based economies, greater integration and interconnection between products, labour and financial markets, spurred by advances in information technology, alliances to remove trade barriers,[28] or liberalization of investment flows and deregulation of national economies. Benefits include: improved quality and better access for local fishery products to foreign markets, increased export earnings generated by fisheries; easier technology transfer for capture and processing; increased productivity and efficiency and better supply of fish products to local populations through liberalisation of imports. A wealthier middle-class is growing in the developing world, as wealth gets concentrated in fewer hands, increasing inequalities across and within nations. Potential negative effects include: exacerbated excess fishing capacity; increased environmental and resource damage; increased competition, on local markets, between the produce of the small-scale fisheries sector and imported low-priced products and appropriation of local resources by large foreign corporations. Major changes in the structure of demand and in the marketing and distribution systems will also have positive and negative impacts. Resistance to change may result in the development of non-tariff barriers, for example, in the form of sanitary regulations and environmental protection measures.

Transnational enterprises moving on global opportunities challenge governments' traditional prerogatives and reduce their capacity for macro-economic interventions. In a fishery *Market World*, these effects will be exacerbated, advantaging large transnational fishing industries over small-scale fisheries, lowering the priority of social (equity) and environmental concerns, reducing the resources available to implement the related inter-governmental agreements, facilitating the growth of IUU fishing as an underground economy, weakening the protection of endangered species and increasing the inequality in the access to fish (UNEP 2003).

Population growth and urbanization will shape fisheries through, for instance, demand for food and pollution. The world population has grown above six billion and is still growing at a rate below 1% per year in Europe, between 1% and 2% in America and East Asia and between 2% and 3% in Africa and South Asia. It increased by 1.6 billion during the past two decades and is expected to gain one billion by 2015,[29] reaching approximately nine billion by 2030 and 2050 and a maximum of 10 billion by 2100 (Lutz *et al.* 2002; FAO 2002). The majority of the growth will be in the developing world, although the impact of HIV-AIDS leads to some uncertainty, particularly in Africa. Population drifts towards coastal mega-cities (UNEP 2003) will continue to increase demand for fish and sea-related livelihoods, providing further incentives for large-scale delivery systems able to cope with massive daily demands, as well as for peri-urban aquaculture. The pattern could be exacerbated by climate-change-driven droughts, triggering massive migrations from agriculture to fisheries, or armed conflicts.

The state of the environment, conserved, enhanced or degraded as it may be by fisheries and other marine and land-based activities, will strongly condition fishery resources abundance, resilience and quality. The assessment of the present situation and future forecast differ greatly between the pessimists (e.g. Brown & Kane 1994) and the optimists (e.g. Lomborg 2001) and the environment crystal ball is even more enigmatic than in fisheries. The Global Environment Outlook (GEO3) elaborated by UNEP (2003) stresses that past forecasts had rightly foreseen the reduction of tariff barriers, the important role of technical innovation and the emergence of a worldwide environmental movement, but failed to foresee important risks such as acidification of the atmosphere, ozone depletion and climate change. Its 2002–2032 forecasts underlined the strategic importance of future environmental governance, stressing the deficiencies and possible negative outcomes of the radical *Market World and* the advantages of the strong balancing role of governments and people (*Policy Reform*). Rhetorical commitments towards sustainability have been made at the highest level in a number of political summits such as UNCED, WSSD and in the United Nations Millennium Goals for 2015 (see www.un.org/millenniumgoals). Expert opinion analysis (Glenn & Gordon 2002) indicates that the end of water pollution, effective oversight, conservation of biodiversity, improved education and better science (all essential for fisheries) are among the ten objectives considered most important, acceptable and achievable in the next 50 years. It also indicates, however, that hunger, pollution, environmental impact and organized crime will nonetheless not be ended, pointing to failure of the *Market World* and the persistence and strengthening of elements of a *Fortress World* in half a century.

In fisheries, the perceptions have progressively shifted during the past three decades following the worsening of the state of the resources, the intrusion of the environmental NGOs in the governmental debates and the development of environmental advocacy. In the 1970s, pollution was considered as a more serious, perhaps more subtle but certainly more long-lasting threat for oceans and fisheries than fisheries themselves (Stevenson 1973; Hennemuth 1979).[30] More recently, and in most cases without any comprehensive comparative analysis, fisheries have been accused of being the main factor of degradation of the marine ecosystems (Jackson *et al.* 2001). The reality is that, during the past 30 years, there has been very little progress in the global understanding of the impact of environmental degradation on fisheries. However, numerous recent papers have underlined the impact of coastal development, fertilizers (nitrates), pesticides, hormones, freshwater flow modification and climate change on aquatic life, its survival, its biodiversity, reproduction and market value (WRI

2002*b*). For inland waters, few experts would disagree with the conclusion that fishing effort is not, in most cases, the main factor impacting the resource. Coastal fishery ecosystems are indeed evolving on a parallel track as the coastal environment is impacted by growing economic activities and artificialization. On a different note, in the medium-term, and no matter how well the environment is conserved, the future of fisheries depends on natural climatic variations on a circa-decadal scale (Klyashtorin 2001; Bakun & Broad 2001) influence of the environmentalist movement on fisheries governance and operational environment has already been substantial, following a general increase in public awareness. It has already led, *inter alia*, to the adoption of the precautionary approach (FAO 1996), the ecosystem approach, the initiation of more elaborated norms for endangered species impacted by fisheries, an increasing support for marine-protected areas as well as a movement to reduce land-based sources of pollution, e.g. through the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. Line ministries in charge of the environment are being established in most countries and fisheries are increasingly forced to assess their environmental impact. In several countries, fisheries are already under a Ministry of the Environment and considering the small size of the fisheries sector in most countries and hence its relatively lower electoral power, this strategy might spread further in the future.

Other driving forces will affect the future of fisheries. Growing public awareness of environmental issues may foster political will and induce a change in consumer habits, and producers' attitudes (through ecolobelling). Civil and international wars are not conducive to fisheries stewardship and may accidentally reduce fishing effort and/or provoke massive migrations into small-scale fisheries, increasing fishery tensions, depleting resources, favouring corruption, illegal fishing and destructive methods (explosives) and facilitate a shift to a *Fortress World*. Information technology and public information can foster education, decision-making, fairer trade, and ultimately impact wealth distribution, transparency and equity. Computers, global databases and knowledge sharing systems, cell phones, global positioning systems and VMS are changing dramatically the capacity to assess, advise, monitor and control fisheries. The increasing rich–poor gap and drop of *per capita* income of the poorest (Glenn & Gordon 2002) may also push more excluded people towards an activity of last resort in fisheries, the last open frontier. HIV-AIDS is more acute in migrating populations and in activities involving long absences from home. Fishermen are particularly prone to infection (ICLARM 2002; Ainsworth & Semai 2000) and the impact on fishing livelihoods, particularly in Africa, may not yet be fully appreciated. Energy prices directly affect fishing operations. As prices of fossil fuels are likely to rise sharply in the next two decades, alternative sources (e.g. hydrogen) are not yet in sight (Rifkin 2002) and subsidies are being phased out, the cost of fishing will rise, raising fish price, reducing demand and accessibility to the poorest, favouring small-scale and static fishing equipment fisheries. Ethical issues are emerging in most areas of development in relation to the use and management of global commons or global public goods and are only being addressed for fisheries (FAO 2005). The Code of Conduct for Responsible Fisheries is, in many ways, a global code of ethics addressing numerous but rarely explicit ethical issues.

(c) *Fisheries scenarios*

In § 2, trends, past forecasts and present state and some specific elements of the fishery system (potential, state of resources, technology, governance, etc.) were reviewed. However, this reductionist view does not easily lead to an overall outlook as the various components of the fishery system interact in a complex way. This section reviews briefly a number of comprehensive forecasts, either as a single scenario considered as the most probable or a set of possible ones. Except for Kearney *et al.* (2002), these scenarios were necessarily based more on their authors' perceptions than on hard calculations. They have generally been proposed without detailed consideration of the driving forces conditioning them or any measure of their likelihood.

Without specifying the reference time horizon, Daan (1989) speculated about the future of the North Sea. Having identified the main current problems, he described three possible options for the future.

(i) *Doing nothing*—leading to a greater decrease in biomass, fishing (mainly industrial) on small species and juveniles of large ones (mainly for fishmeal), disappearance of many species, particularly cetaceans, increased eutrophication, anoxia and mass mortality of bottom animals, epidemics, and proliferation of marine birds.
(ii) *Doing the impossible*—eliminating fishing vessels and oil platforms, fishing and pollution. Daan doubts that in most cases ecosystems could recover to their original (and unknown) form and reckons that conflicts would be unmanageable. As shown by the name he gave to the option, he considers it rather unrealistic.
(iii) *Doing one's best*—recognizing and reconciling multiple uses and the intrinsic value of the North Sea, limiting land-based pollution and dumping, reducing oil spills, establishing area-based use rights (for fishing, oil drilling, shipping, etc.), reducing conflict through geographical segregation, natural reserves, effective effort control (as opposed to catch quotas) and implementation of the precautionary approach, recognizing that multi-species manipulations are beyond our understanding and capacity.

In addition, Daan considers the potential impact of global warming. According to him, this less and less unexpected event would raise seawater levels, displacing people back to higher lands and freeing coastal nurseries. He reckons that this will not affect the North Sea future much beyond some species composition changes and increased anoxia problems.

Pope (1989), presenting it as a facetious exercise, ventured into predicting four caricature scenarios for the North Sea (summarized in Appendix B) which, with minor modifications, could be examined as possible scenarios for all or many of the world's fisheries. The paper highlights the interactions between the overall economic situation and the global climate change with national objectives for fisheries, ranging from maximizing recreation in a rich societal environment to ensuring basic food—probably contaminated—to a poor population lacking alternatives. The scenarios correspond to different sets of societal objectives for alternative use strategies optimizing respectively: (i) recreation; (ii) foreign exchange earnings; (iii) aquaculture production; and (iv) food for the poor and dumping (a strange combination indeed!). Although they were apparently not intended to be taken seriously, they indicate:

(i) The need to decide on and ensure a spectrum of fish sizes and species, which suits the objectives. This, in turn, underlines the need to manipulate the ecosystem (enhance, stock, cull, etc., as appropriate), even in the green scenario based on high species diversity for recreation.
(ii) The considerable role of aquaculture as a co-factor, possibly becoming a driving force.
(iii) The need to better understand the ecosystem and predict recruitment in order to optimize the uses.

Kearney *et al.* (2002) modelled the future of 200 Australian fisheries to 2050, incorporating their yields into a broader mathematical model, including population growth, energy available, total resource use and environmental quality. They suggested future supply and demand scenarios testing predictions against known trends for three scenarios (optimum, status quo and caution). They concluded that, for all scenarios, fisheries production would continue to decline for at least a decade, stabilizing below the levels observed in the 1990s, leading to questioning present management strategies, advocating a more holistic management of fisheries sub-sectors (including recreational fisheries) and including broader ecosystem impacts such as pollution, habitat degradation, etc., resulting from fisheries as well as other uses of aquatic resources.

Ikeda (1998) presents a not-too-optimistic view of potential development to 2010. He reckons that demand will increase globally and that rising fish prices will continue to provide incentives to fishers to increase pressure globally. He predicts that overfishing and increased capture of juveniles will follow, encouraged by the incentives provided by buyers and importers. Contrary to the standard assumption in the supply–demand simulations referred to above, he believes that aquaculture, affected by pollution, diseases, shortage of feeds and water supplies will not be able to fill the gap. He foresees, however, a reinforcement of environmental protection regulations, better science, implementation of closed seasons, development of compensatory schemes for displaced fishers, desperate cost-cutting measures as opposed to revenue-increasing ones, and better use (less waste) aiming at a priority of human consumption. He forecasts the demise of many fisheries and failure of aquaculture to compensate for the disaster despite a reinforcement of governance and institutions in a twenty-first century characterized by population growth, rising demand for food and environmental degradation.

Amaratunga & Lassen (1998) are as optimistic as Beckett (1998) and on the premises that supplies are uncertain and significant new resources are unlikely to be found, concluded that, in the future:

(i) demand will increase most for high-value products and species;
(ii) prices will be boosted up, perhaps reducing/stabilizing demand inz importing countries;
(iii) by 2010, the fish supply deficit will reach 10–40 mt above what the marine fisheries can provide and the role of aquaculture will significantly increase;
(iv) technological innovations in processing and use will improve efficiency of use as well as control of fishing operations through more systematic use of integrated VMS;
(v) world fish trade will further globalize;
(vi) diversification of processing will make vertical integration difficult;
(vii) the CBD will play a greater role;
(viii) the UN will revisit the governance of the seabed use;
(ix) marine reserves will play a greater role in fisheries management;
(x) new effective and selective fishing equipment will be invented;
(xi) the use of energy saving devices will be generalized;[31]
(xii) some types of trawl (e.g. beam trawl) might be banned;
(xiii) fishing operations will be more informed and more controlled, reducing unnecessary risks (e.g. to endangered species) and discards;
(xiv) the past two decades' trend towards high specialization will give way to a trend towards diversification;
(xv) the new management paradigm will account for the need to maintain communities' livelihoods;
(xvi) co-management and transparency will spread;
(xvii) fishing rights will spread and may concentrate, leading to concentration of the industry;
(xviii) reduced fishing will improve the state of the ecosystems;
(xix) research will be reoriented towards policy and operational research;
(xx) more research will be in the hands of industry itself;
(xxi) technological progress (satellites, autonomous samplers; underwater technology, satellite positioning, electronic tagging telemetry) will improve the level of information available.

Cury & Cayré (2001), in a fictitious retrospective description of the evolution of fisheries, supposedly written in 2051, indicate that marine capture fisheries disappeared, as a professional activity, c. 2020. Drawing a parallel with the end of hunting, they indicate that fishing disappeared, under societal pressure from young generations of stakeholders, discredited by conflicts, overexploitation, overcapitalization, demographic pressure, non-precautionary management and development, lack of stewardship, inappropriate institutions and climate change. These pressures and driving forces led to irreversible depletion of most resources. Technological innovations outpaced scientific capacity to predict and institutional capacity to adapt. Science was wasted in conflicts with NGOs and conservation agencies. Long- and short-term objectives could not be reconciled. Fishing rights and eco-labelling failed to provide the proper incentives. Fish prices increased dramatically, turning high-value species into luxury items for developed countries' wealthy consumers, leaving only small pelagic and other prey species to the less endowed. They conclude that this was not planned. It just happened.

Hammond (1998) mentions specifically fisheries in a worst case scenario for the twenty-first century characterized by significant environmental distress. 'One by one, major marine fisheries collapsed, victims of sustained overfishing by huge trawler fleets eager to supply the international fish market. Fish, produced almost entirely by aquaculture now, is a luxury food. Fishermen lost their jobs but more devastating was the loss of the primary source of proteins for three quarters of a billion people… As conditions became desperate, the voices of the disenfranchised became louder. In India a protest march by a group of fishermen became an army of more than 2 million people that converged on New Delhi'.

A large number of more or less explicit scenarios of the future can also be found in the press and these are usually catastrophic, in which overfishing is usually seen as spreading, sending world populations in a 'downward spiral' and millions of people out of work, uselessly waiting for decades for an improbable recovery while the UN promotes non-enforceable treaties and the world ecosystems collapse into anoxic 'dead zones' full of dead coral, jellyfish, blue algae and bacteria (Guterl 2003).

All the above scenarios fit into the typology of future worlds scenarios described above.

(i) *Market World*, with its two variants: (i) *Business as usual* in Daan (1989) and Ikeda (1998); and (ii) *Policy reform:* in Daan (1989); Amaratunga & Lassen (1998); Beckett (1998) and Kearney *et al.* (2002);
(ii) *Fortress World*: in Hammond (1998) and Cury & Cayré (2001);
(iii) *Transformed World*: elements of which can be found in Daan (1989) and Beckett (1998).

4. DISCUSSION AND CONCLUSIONS

(a) *Present state and trends*

As shown in § 2, it is not easy to summarize the global state of the fishery system at the beginning of the twenty-first century, with all its complexity, without dangerous generalizations in which personal experiences, biases and perceptions play a significant role. This average or dominant situation, as perceived by the authors, has been tentatively represented in figure 13 on a system of indicators in which the lowest and highest values correspond, respectively, to the worst and best scenario. For some indicators, the scale is bound by opposite options: for example, government leadership at one extreme versus private corporations' leadership at the other; democracy versus oligarchy; aesthetics (and conservation) versus consumerism; radicalism versus tolerance; consensus versus voting decision processes; compliance versus poaching, etc. In this case, the option considered as 'negative', appearing between parenthesis on the figure, corresponds to the lowest value of the vector. In this framework, the dominant situation of today's fishery sector (corresponding to the *Market World*) has been positioned. For each indicator, the direction of the present forces for change (the direction of ongoing trends) has been indicated. The figure intends to illustrate the fact that the present situation is characterized by contradictory forces. While the agreed conceptual objectives for fisheries policy pull the system towards the best case values, the short-term economic reality and the effects of globalization and market domination pull, in many cases, in the opposite direction.

(b) *What future for fisheries?*

A key question is: how will the system evolve in the future? Which scenario(s), among those outlined for the world or for fisheries will become dominant? Paraphrasing Hammond, will the future bring a *market-driven fisheries world* in which widespread prosperity and stability come from economic reforms (e.g. systems of rights, no subsidies), technological innovation (e.g. improved fishing equipment and processing), improved governance (e.g. participation and liability) and the integration of developing fishing nations into the global economy? Or will it bring a *feudal fisheries world* in which the large fishing corporations get bigger and richer while large portions of the present fisheries workforce is left behind, the environment is irreversibly degraded, and conflicts, non-compliance and instability spread? Is it possible, instead, that social and political change, driven by responsible leadership and grass-root social coalitions lead to a *responsible fisheries world* in which rights and responsibility as well as prosperity are fairly shared and in which the market serves common social and environmental goals as well as private economic ones? Many, if not all, of the driving forces such as market-based economic reforms, technological innovations, democratic proselytism, decentralization and participation, human population growth, etc., have the potential to pull the fishery sector towards a much better or much worse world.

In the absence of a statistical or mathematical solution for the matrix of possible outcomes, the reply to the question above is necessarily subjective, affected by one's natural optimism or pessimism. Leonardo da Vinci, the visionary genius of the 1500s and the first modern scientist, pessimistically predicted for instance that 'nothing will remain on the Earth or under the Earth and the water that is not pursued, removed or damaged'. Lomborg (2001), on the contrary, is adamantly hopeful. Da Vinci's pessimism is apparently shared by Hammond (1998, p. 12) even though, in his conclusions, he suggests that 'both optimistic and pessimistic futures are fully within the range of possibility given the present long-term trends'. By extension, for fisheries, both optimistic and pessimistic futures are possible. Borrowing the framework given by Costanza *et al.* (2000) and Costanza (2001) a pessimistic and optimistic perspective on future fisheries has been developed in Appendix A, illustrating the likely outcomes when the wrong policy options are selected.

Although the best and worst scenarios may appear improbable to some readers, it must be stressed that the diversified situation of fisheries around the world contains embryonic as well as fairly advanced stages of development of all them. Well managed and devastated fisheries coexist sometimes in the same region or country. It is very probable that the future of the fishery sector will also reflect a mosaic of situations, and determining the fisheries' future amounts to determining which mix of scenarios will develop and which one will represent the dominant paradigm, taking account of the possible 'surprises', globally and regionally. Because of the homogenizing effects of globalization, global convergence of the various possible evolutions could be expected, leading to progressive decrease of the diversity of situations in the world. However, the local logics of economic development might instead lead to 'specialization', for example, towards dominance of low-level recreational fisheries in rich countries and intensive fisheries for food and foreign exchange in poorer ones.

(c) *Market world*

If a *Transformed World* of fisheries is the ultimate aim, what is the most likely pathway to it? Gallopin (2002) argued that it was difficult to see how the present *Market World* could lead to it, because of the widening gap it creates between poor and rich, and suggested that only major societal disruptions and wide-scale crises could provide the appropriate incentives. However, planning for a *Fortress World* is not an alternative, even though aspects of it exist already and might spread. Planning for a *Market World* seems therefore to be the only viable option (Gallopin 2002, p. 387), putting in place, however, the necessary social and economic mechanisms to contain its environmental impact at societally acceptable level and deal with inequity (*Policy Reform*).

Under such a dominant scenario, during at least one or two decades, the fishery sector's evolution will be driven by the market, and governments will continue to progressively lose control on it. The evolution of the global economy, energy cost and the rate at which inequity will grow will decide the duration of this scenario. During that time period, and even though globalization will tend to harmonize situations, there will be areas in which weak governments will not be able to counterbalance the market drive with social and environmental policies leading to social unrest and a risk of governance collapse. There will also be areas of fisheries *Policy Reform* in which continuous efforts towards sustainability will be afforded.

However, as shown in figure 13, it would appear that the present situation is unstable, in tension between two extremes: (i) the best case, too costly to reach directly, and (ii) the worst case, too costly once it is reached. Maintaining fisheries in the market world, slowly aiming at policy reform, will have societal costs.

(d) *Transition to a policy reform*

The transition costs from the wild *Market World* to its *Policy Reform* variant are very significant (FAO 2002) and include the cost of the structural adjustment of fisheries, elimination of excess capacity, provision of alternative employment, suppression of subsidies, full management cost recovery, environmental rehabilitation, etc. The pathway to a *Policy Reform World* has already started, particularly during the last decade, and substantial improvements have been made. For example:

(i) discards have been reduced by 50% through better use of the catch;
(ii) the building rate of large vessels has been reduced by 85% (from 2000 to 300 per year);
(iii) the foundation of governance has improved (UNCLOS, UN Fish Stock Agreement, Code of conduct, CBD, etc.);
(iv) the concept of fishing rights is spreading, together with 'fisheries democracy', participation, devolution and decentralization;
(v) public awareness has grown;
(vi) objective alliances have been established between small-scale fisheries and NGOs, the role of which is increasing;
(vii) eco-labelling is progressing, opening the door to consumers' involvement; the question of flags of convenience is on the table and some open registries may soon be closed to fishing vessels;
(viii) serious efforts are being made to curb illegal fishing, reduce capacity in EEZs and cut down on subsidies;
(ix) fish prices have been maintained despite growing demand;
(x) traceability is starting to develop through catch certification;
(xi) large processing industries (for example Unilever) and consumers (for example McDonald's) as well as chains of restaurants are developing internal guidelines and criteria of resources sustainability to guide their trade.

In many cases, however, these improvements are an exception rather than the rule.

In a few areas, *Policy Reform* will be energetic enough to control and reduce fishing capacity at the cost of displacing employment from fisheries to other economic sectors, probably subsidizing the change. The development of environmental ethics, 'greening' of fishing corporations, alliances between industry and environmental NGOs, generalization of use rights, integration of fisheries in integrated coastal area management, etc., will improve the state of the resources, reduce further the already limited importance of fisheries in the national economy and shift fisheries governance under area-based environmental and ecosystem management. Consumption will be maintained through imports that will aggravate the situation in 'Business as Usual' areas. This is already happening in some of the most developed countries. Reconstructing the ecosystems to acceptable (affordable, if not pristine) levels will require curtailing the fishery sector.

Considering the very significant impact of land-based pollution and the societal costs of the comprehensive package of solutions required, a total remission is unlikely—and possibly not even necessary—in the medium-term without a societal revolution. Resilient overcapacity and high demand will therefore continue to converge to destabilize the ecosystems and threaten fisheries sustainability. The overall result of the various evolutions will mainly depend on the interplay between the areas. The market demands for more food fish for the areas where fishing will be curtailed (*Policy Reform* areas) will add pressure on resources in less managed areas (*Business as Usual* and *Fortress* areas). With the ongoing development of surimi production based on multiple species, even low-value species, presently unsuitable for surimi, will be in high demand for richer areas, reducing their availability to poor consumers. The extent to which aquaculture will operate as a regulator of that chain reaction will be fundamental and not without problems regarding the sustainability of that sub-sector itself.

Much remains to be done, however, to conceive new advances and to generalize those already available. It is usually expected that effective corrective action will be taken first in the most developed countries. However, economic development indicators point towards much higher rates of economic growth in Asian developing countries. As this is also the most productive and in many cases the most overfished area of the world, it might be the area in which the transition to a more sustainable *Policy Reform* (or *Transformed World*) or *Fortress World* will be first tested.

The total environmental bill that all governments face is impressive and, in most countries beyond economic capacity. As usual, however, political systems will be eager to show to their environment-conscious electorate that 'something is being done'. There is a big danger that fisheries are used as a 'cheap' scapegoat, ritually sacrificed by politics on the environment altar, while more surreptitious and less carefully documented environmental impacts with much more serious, long-lasting and costly impacts on human well-being (e.g. from the politically powerful chemical and pharmaceutical industries) continue relatively undisturbed.

(e) *Open questions*

Some important aspects of the fisheries' future have apparently not been addressed anywhere, probably because of the general ignorance of the dynamics of the fishery sector, for example, in terms of private investment strategies, trade in excess fishing and processing capacity, impacts of national financial and environmental policies, vertical and horizontal integration (from capture to trade and from capture to culture), as well as integration in coastal area management. These aspects include:

(i) Potential massive transfers of raw material from the developed countries' capture fisheries to developing ones for lower-cost processing, boosting the land-based part of the sector in the latter, as has happened in the tuna industry.

(ii) Development of a fishing manpower trade for use of developing countries' fishers on developed countries' vessels as coastal communities of the latter turn away from fishing activities to more remunerative and easier ones. This has already happened in the past in Australia, USA, Argentina, for example with Italian, Greek and Portuguese fishers. It is happening in the southern regions of Italy and France with North African fishers.

(iii) Accumulation of fishing rights in the hands of few international global fishing consortia, possibly leading to the exclusion of *bona fide* fishermen unable to acquire quotas on competitive markets. This has already happened on a smaller scale and might be accelerated if the access to national quotas is opened to foreigners in the absence of a strict policy regarding transfers of rights.

(iv) The consequence of horizontal integration between capture fisheries and aquaculture, integrating the production of feeds from wild resources and their use in domestic production, optimizing both interacting markets and opening the horizon of marine ranching as an integrated activity. This has happened for instance in Thailand and Spain (with Pescanova). It would reduce negative interactions between the two sectors but may allow the subsidization of overexploited fisheries segments of the consortia, producing trash fish for aquaculture feeds by their commercially successful aquaculture segments.

(v) Global integration of high-sea fisheries in a few large fishing corporations, allowing for an industry-controlled rotational scheme of exploitation of the high seas.

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APPENDIX A. OPTIMISTS VERSUS PESSIMISTS

Costanza *et al.* (2000) and Costanza (2001) distinguished 'technological optimists' from 'technological sceptics'. For the former, technology can deal with any future challenge, the future is a smooth extrapolation of the past and the market is a good guiding principle. The latter, which we could also call 'societal optimists', accept technological development but give priority to social and economic development, recognize market imperfections and natural carrying capacity constraints, hold that the largely unpredictable future contains surprises and therefore requires a precautionary approach. Borrowing this framework, the table below shows the two opposite visions of future fisheries and the consequences if such visions and related policies are indeed correct or wrong. There are obviously other ways of combining the various elements shown in that table and some other elements than those considered could be brought in. As it stands, however, the table intends to illustrate the main directions for future fisheries and the way they might unfold.

		real state of the fishery sector	
		if the vision/policy was right	if the vision/policy was wrong
visions and policies of techno-optimists	fishing technology can evolve to face ecosystem and equity challenges	low-impact technology adopted; small- and large-scale fishing coevolve	high-impact technology dominate; large-scale fishing dooms small-scale
	the market (including consumer controls) will 'fix' most problems for the benefit of all	Eco-labelling fixes the problem; continued growth provides excluded fishers with alternative employment	consumers' willingness to pay is limited; rising prices fuel overcapacity; no alternative employment
	competition for the market will select eco-efficient entrepreneurs	VMS and zero tolerance eliminate illegal and destructive fishing	legal fishing is quasi impossible; armed pirating and conflicts are the rule
	the ecosystem is reversible, predictable and can be modified	ecosystem rehabilitated and enhanced; fluctuations accounted for; rare collapses	degraded ecosystem; unpredictable fluctuations; frequent collapses
	fishing is the main driving force, not pollution	fishing is controlled and reduced; profitability and stocks rebuild; fish is the healthiest food	polluted ecosystems produce less at higher costs; fish is a contaminated food
	aquaculture production will fill supply gap	intensive practices, selective breeding and genetic manipulations will lead to food security	environmental damage; contaminated food; focus on carnivores aggravates overfishing
visions and policies of techno-sceptics	fishing technology will not meet the challenge; better governance will	good governance is in place (ecosystem approach to fisheries, precaution, indicators); long-term interests are valued	fox in the hen pen; short-term interests; lip-service to ecosystem maintenance
	international collaboration can correct market failures	World Trade Organization ruling and zero-subsidies policies lead to economically effective fisheries	free trade dooms local environmental protection; global supplies threatened
	community development is the key, in the context of strong use rights	privatization improves stewardship and compliance; conflicts are resolved locally	privatization leads to concentration, exclusion, and expansion of violent conflicts
	alternative employment can be created/found	overall growth provides alternative jobs to small-scale fisheries; social peace	lack of alternative employment; ghettoes of 'sea-less' fishers in rural areas; social unrest
	the system is complex, nonlinear, naturally oscillating and partly irreversible	ecosystem and precautionary approaches; flexible development; improved forecasts; contingency plans	overriding weight of social risk and political costs in absence of safety nets; insufficient research; poor forecast; costly 'surprises'
	aquaculture and capture fisheries will be integrated (e.g. in integrated coastal area management)	harmonious responsible co-development maintains good and accessible supplies	competition for space and resources, which in the market leads to disruptive booms and busts

APPENDIX B. FUTURE STRATEGIES FOR THE NORTH SEA (POPE 1998).

	societal objective for the North Sea			
criteria	playground (recreation)	foreign exchange earner	fish farm	larder (food and dumping area)
climate	warmer	much warmer	as at present	cool and wet
species	tropicalized + aliens + introduced	mainly pelagics and shrimp	few luxury wild species	'single species' surimi
sea level	high but contained	very high	as usual	irrelevant (?)
fish size	large	small	portion-size	small
ecosystem	manipulated; enhanced, stocked, culling; mandatory environmental impact assessment	manipulated, enhanced; artificial reefs; drowned coastal areas and cities	stocking, artificial reefs; pollution normalized and monitored	high pollution and contamination; strongly modified
fishing activity	very low	high effort; depressed economics; offshore fisheries leased out	none in coastal area; reduction of fisheries in deep water	state-owned fleets
farming	very active	trash fish used as fish food; exotic species for high-end markets	very active; automated; ranching	no role
recreation	high (local)	high (tourism)	low (no time)	low (not exciting)
conservation	high	kills of juveniles; high bycatch	low	low
management	eliminates most fishing to keep high abundance and species diversity	seasonal closures; taxes; effort leased out to best bidder; taxes supporting aquaculture	sea enclosures; industrial transferable quotas; few operators produce maximum economic yield	maximizes proteins supply: effort limits; technical measures; equal pressure on all species
wild harvest	luxury, limited	limited	low	high in ambient malnutrition
economy	prosperous	declines	very wealthy; industrious people	poor; malnutrition
employment	low	low (local)	high	unemployment; jobs in polluting industries
trade	imports high	imports low; exports of shellfish	imports low	?
role of science	species introductions; forecasts; assessments	weak, FAO-supported	modest; mainly privately funded	surveys

ENDNOTES

[1] The highest figures, based on estimates of marine biomass and assuming rates of harvest at the various trophic levels at least one order of magnitude larger than the present one, do not have much credit today.

[2] It is not clear whether Gulland's estimates took discards into account. Considering the rapid development of long-range specialized fleets during the period, however, some of the 27 mt of discards (on average) estimated by Alverson *et al.* (1994) for the early 1990s were probably already caught in the late 1970s and early 1980s, improving Gulland's forecast.

[3] Twelve of these species produce 40–50% of the world catch, the second half of which is produced by 538 other species.

[4] These numbers are extracted from figure 11.2 in Klyashtorin (2001).

[5] The first estimate of world discards by FAO (17–39 mt with a central value of 27 mt, made for FAO by Alverson *et al.* (1994) and reflecting the situation in the 1980s and early 1990s has been considered an overestimate and was informally revised shortly after to *ca.* 20 mt (FAO 1997). A still ongoing reassessment (Kelleher 2003), with more data covering the last decade, indicates a significant decrease to probably less than 10 mt.

[6] The potential impact of ocean fertilization (with iron) remains to be demonstrated.

[7] They found that the average trophic levels in catches declined in most regions of the world, most markedly Northwest and Northeast Atlantic.

[8] These concerns were addressed more thoroughly in the recent work by IFPRI and ICLARM to include fish in the world food model (Delgado *et al.* 2003).

[9] Despite earlier statements that fish consumption was predetermined, equal to production and independent of price (cited by De Silva 2001).

[10] In other words, what decreased is assumed to decrease in the future too, at a lower rate of decrease, and vice versa.

[11] Competition among poor consumers for inexpensive species and aquaculture feeds was excluded from the model assuming that these two destinations were coming from different and non-interacting fisheries. This constraint may however not hold in the future if globalization and overall demand increase.

[12] Stabilization of exports relative to imports and of local consumption relative to exports.

[13] Mainly related to shrimp (Crustacea, Decapoda) and salmon culture.

[14] This section has benefitted greatly from the assistance of Andrew Smith, Fishing Technology Service, FAO Fisheries Industries Division.

[15] In several countries (e.g. Sweden, USA, Italy), warnings have already been issued against the use of some parts of the fish (fat, skin, entrails), advising pregnant women against eating fish more than once a week. The European Commission regulations on dioxine already exclude fish from some areas from trade and consumption.

[16] According to Andrew Smith, the coverage of the Lloyds database was *ca.* 70% in the 1970s and is now *ca.* 96% of the world fleet of vessels of 100 t or more (*ca.* 24 m length and more).

[17] Distant-water fishery landings are here defined as quantities taken by vessels in all FAO major fishing areas other than those adjacent to the flag State. Their evolution has already been analysed by Grainger & Garcia (1996).

[18] As Larkin (1972) put it, a summary assessment of science and management performance would require 'twenty pages for introduction, one page for results, and hundred pages for rationalized excuses'. A statement confirmed in Alverson & Larkin (1994) and still largely valid 10 years later.

[19] Particularly in the area of illegal fishing and the problems created by flags of convenience, i.e. in the 1993 FAO Compliance Agreement, 1995 UN Fish Stock Agreement and 1995 FAO Code of Conduct.

[20] The two modes refer to the terminology of (Novwotny *et al.* 2001).

[21] This is the case in the USA where the National Marine Service scientists were facing more than 150 lawsuits in 2002.

[22] The wealth of socio-economic works relating systems of governance and resources conservation or depletion remind us that these scenarios are not purely fictitious constructions (Braudel 1986; Ostrom 1990, 2000).

[23] Gallopin (2002) finds it difficult to conceive how the *Market World* would lead directly to a best case scenario that he rather sees as emerging from global perception of environmental stress and global risk for the ecosystem and its inhabitants, global warming with catastrophic consequences and the realization of the futility of social polarization.

[24] The stock market is unstable, showing threats of collapse as major economic powers struggle against deflation.

[25] The world oil reserves are plummeting and, unless new forms of energy are rapidly detected, serious problems for the present dominant civilization may materialize within 2–3 decades (Rifkin 2002).

[26] Through the expansion of long-range fleets, increased market flows, transfers of technology, improved information flows, trade liberalization, pressure to eliminate subsidies; awareness of environmental impacts, demands for decentralization and participation, increasing demand for use rights, etc.

[27] See http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/issues/

[28] The example of the campaigns in the US against the imports of Vietnamese cultured catfish may be exemplary of the behaviour that can develop in this respect (Fighting dirty over catfish, Herald Tribune, 23 July 2003).

[29] Data from World Bank, 2002, http://www.worldbank.org/depweb/english/modules/social/pgr/chart1.html).

[30] It might be useful in this respect to note that the total disappearance of the Southern Aral sea is now predicted for 2018 (Agence France Press, 21 July 2003), a result no fishery can achieve.

[31] They also noted that the combination of efforts to save energy, reduce bottom impacts and improve selectivity may lead to elimination of trawling in favour of gillnetting.

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GLOSSARY

EEZ: exclusive economic zone
IUU: illegal, unreported and unregulated
MSY: maximum sustainable yield
NGO: non-governmental organization
RFMO: regional fishery management organization
VMS: vessel monitoring system