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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).

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

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.

(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

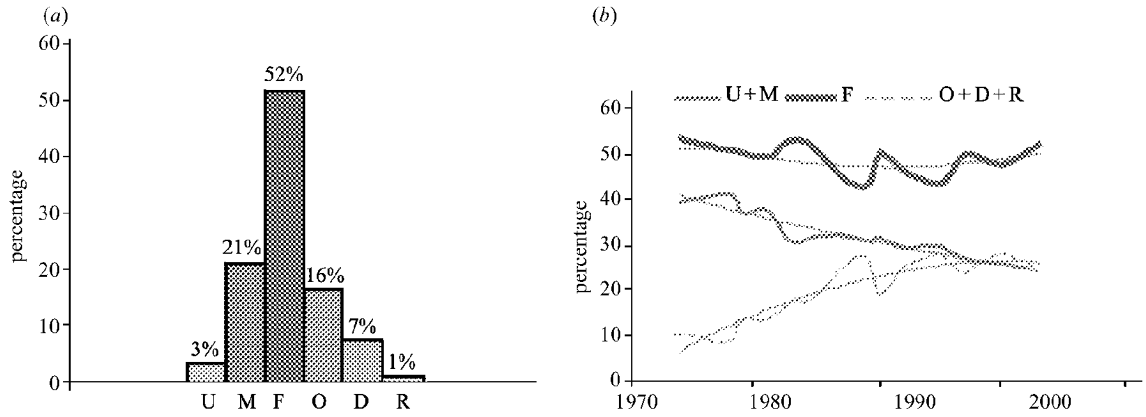

Figure 1. State of world fish stock items in (*a*) 2003 and in (*b*) 1974–2003. U, underexploited; M, moderately exploited; F, fully exploited; O, overfished; D, depleted; R, recovering.

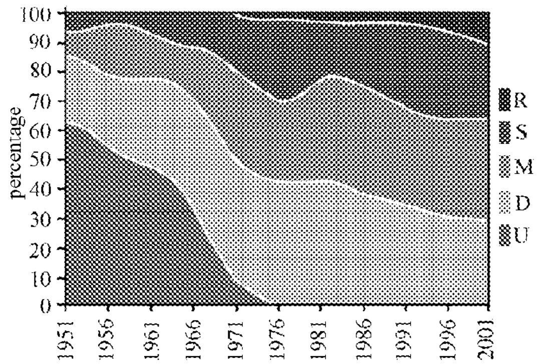

Figure 2. Percentage of major marine fishery resources in various phases of development with five-year intervals: 1950–2001. U, undeveloped; D, developing; M, mature; S, senescent; R, recovering. (Modified from Grainger & Garcia (2004).)

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.

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