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— INVITED REVIEW —

Global fisheries: a brief review

DANIEL PAULY*

Fisheries Centre, University of British Columbia, Vancouver, V6T 1Z4, Canada

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The period following the end of the Second World War saw massive catch increases in fisheries, particularly in the 1960s. However, crashes due to over-fishing began to be reflected in global catch trends in the 1970s, and intensified in the 1980s and 1990s. In response, the industrialized countries of the Northern Hemisphere, where over-fishing-induced catch declines appeared first, moved their efforts toward deeper waters, and toward the south, i.e. to the coasts off developing countries, and beyond into the Southern Hemisphere, all the way to Antarctica. Now, in the first decade of the 21st century, the global expansion of fisheries is completed, and global catches, which peaked in the late 1980s, continue to decline, and the collateral damage to marine ecosystems and biodiversity continues to increase. Several factors act to prevent the public in developed countries from realizing the depth of the crisis fisheries are in: over-reporting by China; the fact that FAO combines declining fisheries catches with strongly increasing aquaculture production; increased consumption, in developed countries, of seafood from developing countries; and widespread denial by governments of the magnitude of their problems. In this review, the scientific developments which have led to a fisheries science being captured by fishing industry interests are summarized and the outlines of a new "fisheries conservation science" focused on the maintenance of the ecosystems of fish populations are briefly sketched.

Key words: catches and landings, discards, fishing effort, subsidies, management.

INTRODUCTION

Global fisheries statistics exist since 1950, as part of the United Nations' effort to generate statistics suitable for monitoring the development of the world economy (Ward, 2004). With some limitation to be discussed later, the statistics assembled and maintained by the Food and Agriculture Organization of the United Nations (FAO) allow tracking the growth and expansion of fisheries by country and region of the world, and globally (Fig. 1).

In the 1950s and 1960s, fisheries grew enormously in terms of effort whether number of boats, cumulative horsepower of fleets, or other measures. During these two decades, however, the growth of fishing effort led to catches increasing at a rapid rate (Fig. 1).

Although the collapse of fisheries as a result of over-fishing had happened previously (e.g. California sardine in the 1950s, Peruvian anchovy in the early 1970s, several stocks of Scandinavian and North Sea herring), they did not alarm the public, as they seemed to be confined to small pelagic fishes, whose volatility was ascribed to environmental factors.

Thus, these collapses did not change policy, e.g. in the North Atlantic, and neither did the fact that catches from this area, the birthplace of industrial fisheries, and of fisheries research, peaked in 1975 and have been declining ever since (Pauly & Maclean, 2003). Instead, effort intensified, particularly in deeper waters (Morato *et al*., 2006). Moreover, the fisheries of the industrialized countries of the Northern Hemisphere began to spill over into subtropical and tropical waters (see Alder & Sumaila, 2004) and then into the Southern Hemisphere (Pauly *et al*., 2005). Simultaneously, the countries of what was then called the Third World began to industrialize their fisheries,

* Corresponding author: e-mail: d.pauly@fisheries.ubc.ca

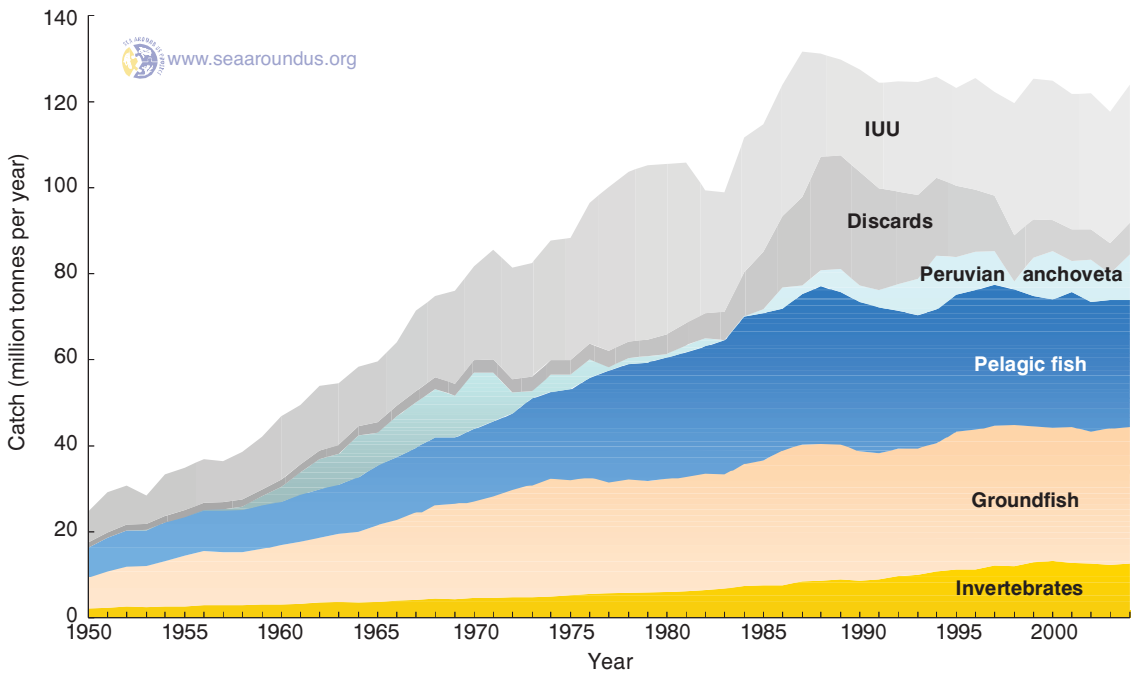

FIG. 1. Global marine fisheries catches, 1950-2004. This graph differs from the "official" (FAO) version of catch trend in that it accounts for i) catch over-reporting by China (Watson & Pauly, 2001); ii) discarded by-catch (Zeller & Pauly, 2005), and iii) other IUU catches, based on Figure 1 in Pauly *et al*. (2002). Note that the discards and other IUU estimates are very tentative, but their values are certain to be considerable.

often with the explicit aim of providing a cheap and healthy food to their growing populations.

The 200-nautical miles Exclusive Economic Zones which, as a result of UNCLOS (United Nations Convention on the Law of the Sea) became the norm in the early 1980s, did not lead to much improvement of the gradually degrading status of the world fisheries. Rather, lured by the promise of marine riches which were now "theirs", most countries, developed and developing alike, encouraged through massive subsidization schemes the development of their fisheries.

Thus, we now have:

- Existing fleet over-capacity is two- to three-fold (Mace, 1997; Pauly *et al*., 2002), and subsidies to fisheries exceed 30 billion US$ annually (Sumaila & Pauly, 2006, 2007).
- The biomass of the large fish traditionally targeted by fisheries has been reduced to a tenth or less of the level it had at the onset of industrial fishing (Christensen *et al*., 2003; Myers & Worm, 2003).
- More than half of the world's fish are consumed in a country different from where they were caught. More precisely, seafood flows increasingly from developing to developed countries, resulting in reduced supplies in protein-deficient, least developed countries (Kent, 2003; Alder & Sumaila, 2004).
- An increasing fraction of the world's forage (small pelagic) fishes, normally the food of large fish, seabirds and marine mammals, is being diverted to feeding carnivorous farmed fish such as salmon, tuna or groupers (see contributions in Alder & Pauly, 2006).

What are the factors which allow this crisis (of economic waste, of basic equity between people, and of biodiversity) to fester?

FOUR FACTORS MASKING THE CRISIS OF FISHERIES

To the non-specialists, and to consumers in developed countries, this crisis of fisheries is masked by four phenomena:

- Since the early 1980s, China has been massively over-reporting its marine fisheries catches to FAO.
- The FAO, in most of its press releases [e.g. those accompanying the release of the latest edition of SOFIA (FAO, 2006)], pools fisheries catches (decreasing slowly) with aquaculture production (increasing sharply; but see below).

- The seafood demand of developed countries is increasingly being met by imports from developing countries.
- Governments and government- or industry- affiliated fisheries scientists continue to assert, through Lomborg-like denials, that fisheries are fine, despite evidence for the contrary.

Although previously suspected by a number of fisheries and other scientists, the scope of the marine fisheries catches over-reporting by China, which amounted to at least five million tonnes in the late 1990s (Watson & Pauly, 2001), surprised many. The key reason is that China lacks an independent system of data for collecting statistics from its primary industries. Rather, the statistical reporting systems are part of institutions run by individuals whose status and promotions depend on reporting positive outcomes. This often leads to manufacturing of data, particularly in areas such as fisheries, where state (and parastate) enterprises dominate (Pang & Pauly, 2001).

The FAO acts on behalf of its member countries, and thus it must accept and report the statistics they submit [although, since the Watson & Pauly (2001) paper, world fishery statistics are presented with and without China]. The Fisheries Department of FAO, however, has its own reasons not to be seen as presiding over a sunset industry, and hence it usually combines, at least when dealing with the mass media, the landings from capture fisheries with the production from aquaculture (see FAO, 2006). As the latter is a booming industry, at least in China, this leads to a grand total that is increasing and all seems well.

The consumer in developed countries, notably the EU countries, the US and Japan, meanwhile, are increasing their per capita fish consumption, which implies, *par force*, a decreased consumption in the developing world (remember that overall supply is decreasing). However, consumers in developed countries, through their high purchasing power, are largely insulated from the increased scarcity of wild caught fish, and can even choose to eat "sustainably" caught fish, no matter how dubious the effects of such choices are (Jacquet & Pauly, 2007, 2008).

Dealing, finally, with the denial of a crisis by governments should be easy. After all, denying for as long as possible the existence of trends (e.g. global warming) which would force them to intervene against powerful interests (e.g. the automotive and energy industries) is what governments usually do. However, these denials are often expressed by government- or industry-affiliated scientists hiding behind the concept of "scientific uncertainty", i.e. the fact that even well-established scientific knowledge may still be affected by errors, and may be revised by subsequent studies. And since some uncertainty is always attached to scientific results, denial of negative trends, e.g. fisheries stock depletions, can continue until it is too late to intervene (Ludwig *et al*., 1993), notwithstanding the precautionary principle. When additionally, such denials are combined with attacks on the integrity of those who reported the negative trends (see Lomborg, 2001, or Hilborn, 2006 for the case of fisheries) substantial delays can result in resolving the problem at hand, if ever.

HOW DID WE GET INTO THIS?

While pre-industrial fisheries had the capacity to extirpate some freshwater and coastal fish populations, as evidenced in the archeological records, it is only since the advent of industrial fishing that the sequential depletion of coastal, then offshore populations of marine fish has become the standard operating procedure (Roberts, 2007).

In the North Sea, where British steam trawlers were first deployed in the late 19th century, it took only a few years for the accumulated coastal stocks of flatfish and other groups to be depleted, and for the trawlers to be forced to move on to the Central North Sea, then further, all the way to Iceland (Roberts, 2007).

Similar expansion processes occurred, albeit a few decades later, in other parts of the world, and this led, after the Second World War, to massive increases of fisheries catches in the North Atlantic and the North Pacific, as well as in South East Asia. By the late 1990s, the last large shelf areas previously not subjected to trawling had been depleted, as were a number of oceanic seamounts and plateaus, including those around Antarctica (Pauly *et al*., 2005). All that is left for the expansion of bottom trawling are populations of demersal fish (at 1-3 km deep), whose extremely low growth rates, associated with extremely high longevity, essentially preclude sustainable exploitation (Pauly *et al*., 2003; Morato *et al*., 2006). Hence, in the absence of legal protection, they are subjected to "pulse-fishing" by distant water fleets of various industrial countries (Bonfil *et al*., 1998), i.e. to rapid depletion of their biomass, without even the pretense of some form of responsible fishing.

Similarly worrying trends are occurring in open water ecosystems, where long-lining for tuna and other large pelagic fishes depletes these systems of large predators (Myers & Worm, 2003), including sharks, now feeding an insatiable fin soup market (Clarke *et al*., 2006). Also, purse seining around floating objects (i.e., natural or artificial fish aggregation devices, or FAD) has made previously inaccessible small tunas and associated organisms vulnerable to fishing, thus prompting fears for the drastic decline of fish populations previously thought largely immune to our depredations.

The change in demersal and pelagic ecosystem structure resulting from such serial depletions can be illustrated in various ways (see Fig. 1 in Stergiou, 2002). One of these is through examination of the mean trophic level of fish in fisheries landings, which are declining throughout the world. This implies that, globally, fisheries increasingly rely on fish originating from the bottom of marine food webs, i.e. on the prey of larger fishes (Fig. 2). Another is by plotting against time the global numbers of exploited "stocks" whose declining catches, in the presence of continuous high effort, suggest a decline in status (i.e. from fully exploited to over-fished, and thence to collapsed; see Fig. 3), and hence a decline in the underlying biomass.

Jointly, these various trends have led to global catches that have been declining in the last decade of the 20th century. In addition, contrary to what was assumed until very recently, the results from newly exploited stocks are not compensating any more for widespread stock collapses.

WHAT CAN WE DO ABOUT IT?

There are two disciplines presently working on the status of marine wildlife and on the fisheries depending thereon: Fisheries Science, founded at the end of the 19th century as an applied discipline, and Conservation Biology, founded at about the same time as a terrestrial discipline, but which recently turned its gaze to marine organisms and ecosystems. These two disciplines – like all scientific ventures – have their own standards and aims, as articulated by leading practitioners, and their seminal contributions in specialized journals. Both also have different "clients": fisheries scientists most frequently work for government laboratories, and their work is ultimately aimed at facilitating operations for the fishing industry. On the other hand, conservation biologists tend to be university-based, and they often work for conservation-orientated non-governmental organizations (NGOs).

Unfortunately, these parallel tracks lead to many problems, starting with mutual lack of recognition for each other's achievements, and often leading to confrontations that are increasingly less justified, given the enormity of the challenge caused by relentless overexploitation of fisheries resources, and their impacts on ecosystems, both culminating in the negative trends documented in Figures 2 and 3.

The elements of reconciliation between fisheries and conservation biology can thus be readily identified. Notably they must include recognizing the legitimacy of the key tenets of each: that fishing should remain a viable occupation and that the ecosystems and their biodiversity are allowed to persist.

One area where this reconciliation would most rapidly yield significant advances is ecosystem modeling, whose importance has increased with increasing demand, also by the public at large, for a transition from single-species to ecosystem-based management of fisheries (Pikitch *et al*., 2004). This transition, which requires a move away from the single-species assessment and management that has so far driven Fisheries Science, will require, for example, leaving enough "forage fish" for exploited populations of large predators, as for populations of protected marine mammals and birds.

Other areas of intervention are:

1. Marine protected areas are increasingly seen as part of any scheme with a chance of success in putting fisheries on a sustainable basis. Unfortunately, they presently cover a cumulative area of about 0.7% of the world's oceans, and the annual increase of their cumulative area (about 5%) is not high enough for various internationally agreed targets to be reached, e.g. 10% coverage in 2010, as agreed by the Parties of the Convention for Biological Diversity (Wood *et al*., 2008).
2. Fishers should have predictable access to the resources, through equitable allocation agreements. Many fisheries economists, strangely, describe this as "rights-based fishing", and thus turn a straightforward proposition (that fishers and fishing firms must be able to plan their operation) into an ideological argument, i.e. that public resources must be privatized before they can be managed properly (see Macinko & Bromley, 2002, 2004).
3. Eco-labeling can involve the public in preferentially purchasing fish from sustainable fisheries. The London-based Marine Stewardship Council (MSC) is the most prominent initiative of this sort,

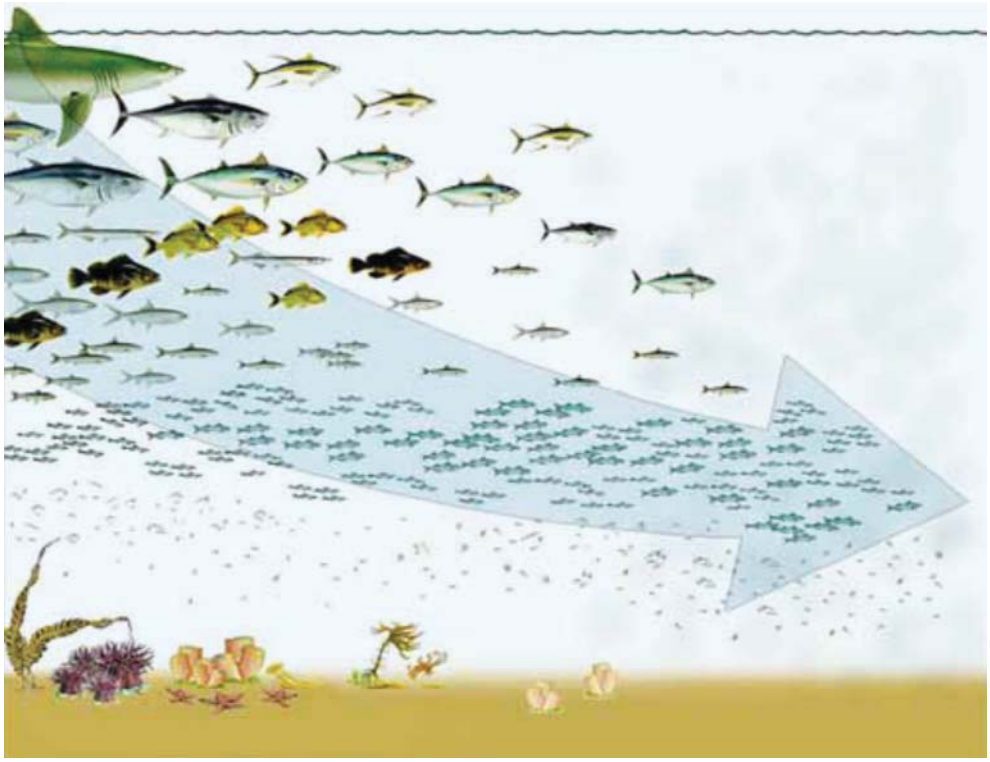

FIG. 2. Schematic representation of the process now known as "fishing down marine food webs" in which fisheries first invariably exploit the larger fishes in an ecosystem (insofar as the current gear technology allows it), then gradually move down as the higher trophic levels are depleted. The original demonstration of this process involved declining time series plots of mean trophic levels of the fisheries catches of various ocean basins (Pauly *et al*., 1998). Such plots, for more limited areas, have now become common in marine ecosystem research.

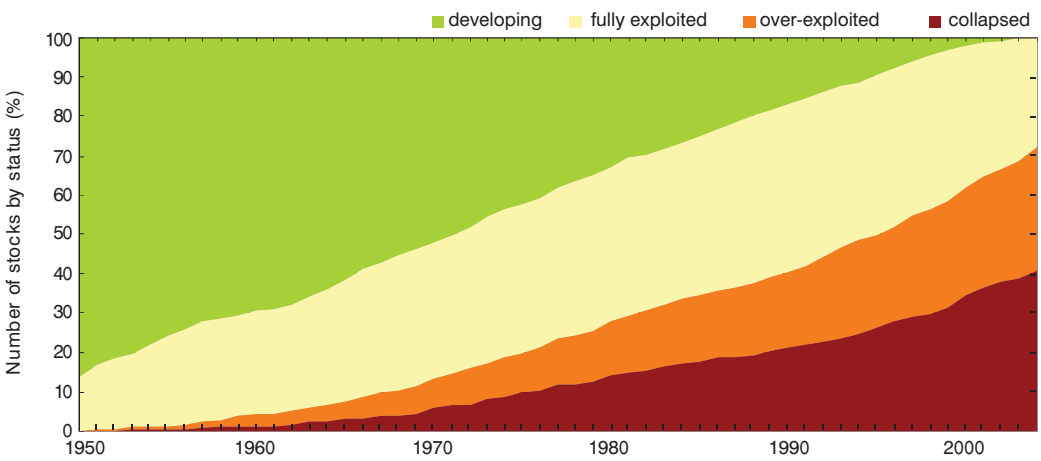

FIG. 3. Trend is the status of the stocks exploited by the world's fisheries, as assessed using the following criteria (all referring to the maximum catch of each stock): developing (catches < 50%); fully exploited (catches ≥ 50%); over-exploited (catches between 50% and 10%); collapsed (catches < 10%). The percentage of stocks of a given status shows a rapid increase of the number of over-exploited and collapsed stocks (based on data by "Large Marine Ecosystems", available at www.seaaroundus.org).

along with the credit card-sized advisories, which, in the US tells customers whether the species offered in restaurants are "good" or "bad" in terms of the sustainability of the fisheries they come from. However, the effectiveness of these market-based initiatives still needs to be established (Jacquet & Pauly, 2007, 2008).

4. Subsidies, which are responsible for the over-capacity of many fisheries, are also their Achilles' heel. Globally, these subsidies amount to 30-34 billion US$ (Sumaila & Pauly, 2006, 2007). Hence, the over-capacity problem could be addressed by the World Trade Organization, whose mandate covers the eventual abolition of all government subsidies.

CONCLUSIONS

Two distinct futures can be readily identified for fisheries science and management. One would continue with business as usual, including the present trends of over-capacity, and serial depletion of fish resources, as manifested in the fishing down marine food web phenomenon, along with the denial that these things happen (see above). The other would lead to fisheries science and management moving away from the establishment of annual catch quotas as its main task, toward ecosystem-based fisheries management, and with a strong reliance on spatial closures (including no-take Marine Protected Areas) as a tool for resource conservation. It would lead, eventually, to the emergence of "fisheries conservation science", with RA Myers as one of its founders (Pauly, 2007).

This entails, as well, a change from the present perception, current among fisheries scientists, that "engagement" for the environment, i.e. for the maintenance of the ecosystems that support fisheries implies a loss of scientific credibility. After all, nobody would ever suggest that medical doctor's passionate commitment to the health of their patients implies biased science. Indeed, it is this very commitment that drives the best of medical research. Clearly, there is an example that fisheries science could do well to emulate.

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