Ecosystem impacts of the world's marine fisheries

It was in the 1990s that fisheries emerged from their sectoral backwaters, and became one of the environmental concerns of the public at large – at least in the developed countries of the world. This transition in public perception, similar to that involving forestry in the 1980s, was probably due to long established trends suddenly generating media events. For example, the revelation of the enormous quantity of 'by-catch' that is discarded by industrial fisheries – around 30 MT/yr, or one quarter of the world marine catch [1], the demonstration that fisheries are "fishing-down marine food-webs" [2] (Figure 1), the reporting of the collapse of Northern cod in Canada [3], and the presentation of first estimates of the subsidies that contribute to maintaining the global fishing effort at three or more times the optimal level [4,5]. These reports were only the tip of a gigantic iceberg: fisheries, an industry that had long operated beyond public scrutiny, emerged, to an amazed public, as worse for ocean health than pollution about which so much is written [6], and fishers, whose daring and ingenuity had for centuries justified the public's romantic view of their profession [7], have become cogs in the high-tech machine that reduces any stock it touches, almost instantly to a shadow of its former self.

The onset of the 21st Century only heightened these concerns. It was demonstrated that present depletions are only accelerating trends that started millennia ago [8], that, contrary to official data suggesting continuous increases, global fisheries catches have been declining since the late 1980s [9], and that modern industrial fisheries do indeed generally require only 15 years or less to reduce the biomass of larger fish, such as cod, or tuna, by a factor of ten. Fishing-down marine food-webs [2] occurs when fisheries, faced with decreasing biomass and catch of large, high trophic level fish (i.e. fish feeding at the top of marine food-chains), target small fish and invertebrates (shrimp, crab, squid) – that is, the prey of the larger fish. In marine ecosystems these 'forage' fish usually consist of

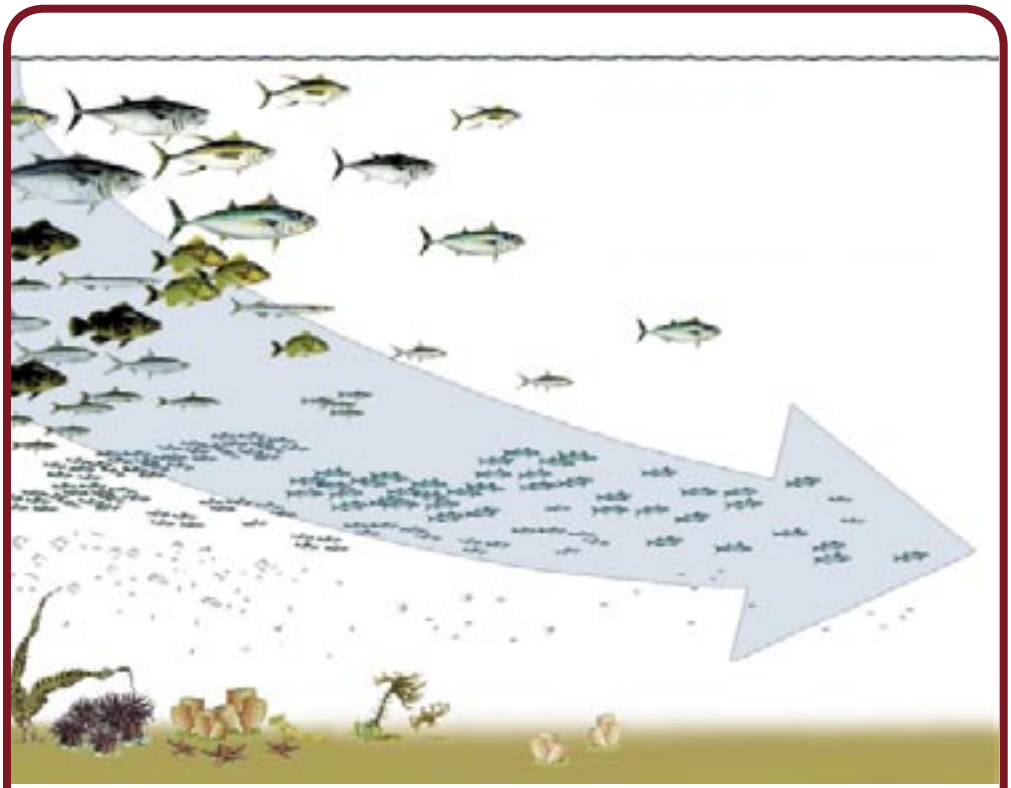

Figure 1: Fishing-down marine food webs, where fisheries, after depleting the large fish at the top of marine food chains (trophic level 3.5-4.5), target the small fish and invertebrates at lower trophic levels. Note the disappearance of biogenic sea bottom structures due to bottom trawling [11].

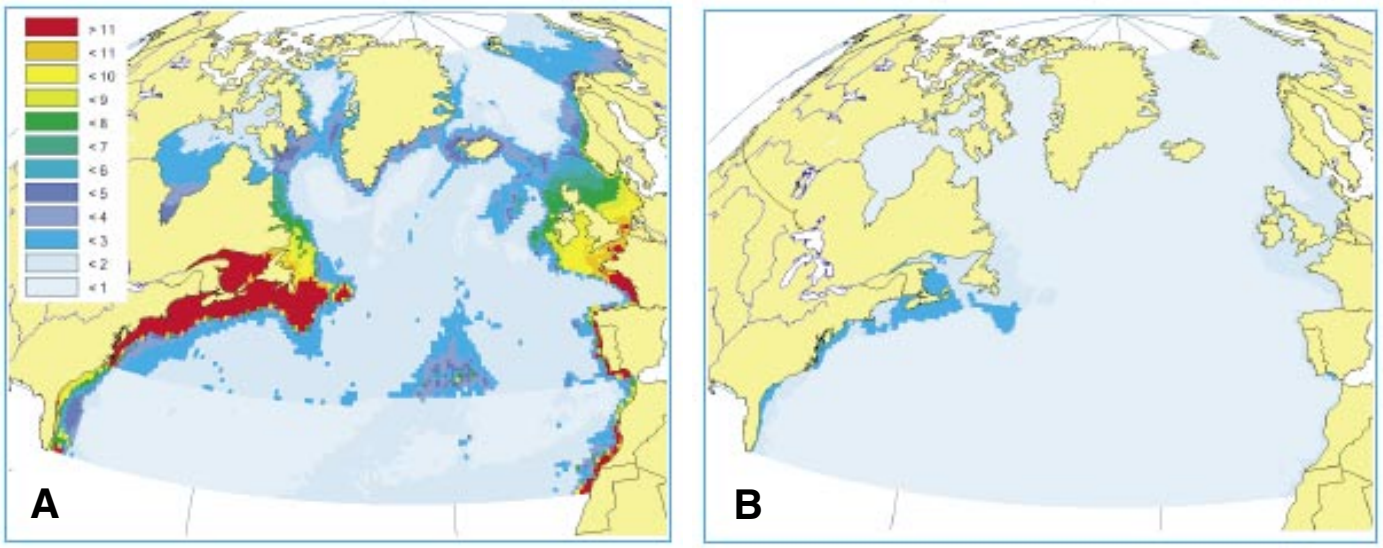

Figure 2: Fisheries-induced change in the biomass (t/km^2) of 'table' fish (trophic levels 3.75 and above) in the North Atlantic. A: 1900, B: 2000 [12].

species of the families *Clupeidae* (herrings, sardines, anchovies), *Scombridae* (mackerels), and *Osmeridae* (capelins and other smelts). These species are commonly referred to as 'small pelagics', because they tend to be only 10-30cm in length and live in open or pelagic waters. Small pelagics tend to form large, dense schools, making them easy to catch with a small expenditure of fuel, especially in comparison with bottom fish, that are typically caught by bottom trawling. Small pelagics play a crucial role in most ecosystems because they transfer energy from plankton to the larger fish and marine mammals. The direct dependence of small pelagics on plankton – itself impacted by environmental fluctuations, often causes their biomass to fluctuate wildly. This has led many fisheries scientists to conclude, erroneously, that fisheries have essentially no impact on small pelagics, and that their abundance is determined overwhelmingly by environmental factors.

Presently the global marine catch of small pelagics is about 40 MT/yr – about one third of the total global marine catch. Most of this catch is used to produce fish meal and fish oil for use in agriculture and aquaculture. The expanding aquaculture industry, especially salmon farming, is increasing the demand for fish meal. This is met in part, by a greater fraction of the mean global fish supply being diverted to aquaculture and away from agriculture, and in part, by increasing the pressure on small pelagics, including species that were previously unexploited. The intense pressure on small pelagics has several consequences, but most notably a depletion of the food base for marine mammals and seabirds. Indeed, this effect is so strong that in many parts of the world it has caused massive declines in seabird and/or marine mammal populations, for example, in the Mediterranean and in the coastal waters of Peru.

Another worrisome aspect of fishing-down marine food-webs is that it involves a reduction in the number and length of the pathways linking food fish and primary producers, and hence causes simplification of food-webs. Diversified food-webs allow predators to switch between different prey as their abundance fluctuates. Given a global decline of 0.05-0.10 per decade in the trophic level of catches, the chance of empirically demonstrating ecosystem-level shortening of food-webs is slim. This does not mean however, that the process is not taking place – a problem similar to the demonstration of global climate change effects.

As the food-webs are simplified by the removal of mid-trophic level components, the large predators find themselves at the top of short, linear food chains that are incapable of buffering environmental fluctuations. This effect, combined with the drastic reduction in the number of year classes in predator populations, makes their overall biomass strongly dependent on annual recruitment. This contributes to increasing variability, and to a lack of predictability in population sizes and hence in catch predictions. The net effect is ironic: it will increasingly look like environmental fluctuations drive fisheries, even where they originally did not.

Among professional fisheries scientists the crisis of fisheries is still often denied. Despite frequent and fashionable references to the need for a methodological 'paradigm shift', many believe, for example, that

rigorous quantification of the uncertainties involved in stock assessment, and the communication of the results to fisheries managers in the form of risk assessments, would be largely sufficient to resolve the above-mentioned problems. Our key problem however, is not 'uncertainty', or lack of knowledge by fisheries managers. Indeed, the problem is not even one of management but one of public policy. This refers to the excessive role played, in allocation debates, by the users of fisheries resources vis-à-vis the true owners of these resources: the citizens of the various countries whose fish stocks are pillaged. Resolving this allocation issue requires public involvement, as occurred for example, with the reclaiming of public waters, long perceived to 'belong' to those who used such waters to cheaply dispose of toxic effluents. Indeed, reclaiming the sea from its abusers will be a key task for the 21st century, second only to avoiding the massive climatic change that will result from the increasing emission of greenhouse gases.

Informing the public, and the law-makers who represent them, of the true status of the impact of fisheries on ocean health is however difficult, because a strong lobby exists which, like the Tobacco Institute with regards to the effects of cigarettes, challenges the obvious to maintain the unacceptable. A similar situation prevailed in the 1950s with regards to the indiscriminate use of pesticides. This was challenged by a compelling case, articulated in Rachel Carson's *Silent Spring*, which affected public policy via its public impact [13].

This was the reason why in 1999 the USA-based Pew Charitable Trusts initiated the *Sea Around Us* Project, based at the Fisheries Centre, University of British Columbia, Vancouver, Canada. The project is named after one of Rachel Carson's other books [14] and is devoted to documenting, both for scientific and for lay audiences, the global impact of fisheries on marine ecosystems, and to contributing to policy debates on how to help mitigate those impacts (www.saup.fisheries.ubc.ca). The project differs from many other fisheries projects in that it has a global scope and a long time-scale – most of the time series produced range from 1950 to the present, with the result that long-term fisheries trends at basin and global scales can be documented. For example, the project re-evaluated world fisheries catch trends to establish that fisheries catches have been declining since the late 1980s, contrary to statistics published by the Food and Agriculture Organisation of the United Nations [9]. The results of the *Sea Around Us* project are perhaps best illustrated by Figure 2, and are further documented at www.saup.fisheries.ubc.ca. Comments and collaborations are invited.

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