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# Ecological impacts of fisheries on marine food webs

## *Keynote:* 'Fishing down marine food webs' as an integrative concept.

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The 1990s have seen so many accounts of a global crisis in marine fisheries and of fisheries impact on their supporting ecosystems being published in mainstream publications, that yet another restatement of the crisis may appear superfluous. Yet the expansion of fisheries effort continues, the subsidies, which drive this build-up, continue, and more stocks throughout the globe are being pushed to the point of collapse. Thus, one can legitimately infer that the message has not yet reached decision-makers of sufficient stature.

The conference documented in this report may be seen as another attempt to get the message 'across'. Given the grim nature of that message, this first contribution is to establish the strength of the ecosystem impacts alluded to above, and thus to provide a base for later contributions. These will then describe the economic and other societal ramifications of these impacts, before proposing remedial measures.

However, for the sake of clarity and space, we shall limit ourselves, when describing the ecosystem impacts of fisheries, to a limited set of such impacts. Hence, we concentrate on the impacts fisheries have on food webs, i.e., on the network of flows of matter (= biomass), which in ecosystems, link the plants with the herbivores, and the latter with their predators. These networks of flows are affected directly by fishing, which removes predatory fish, or competes with them for their preys, in either case affecting the web within which predators and preys are embedded.

Figure 1 gives an example of a simplified food web, and defines the various elements of such webs ('functional groups'), the flow between them, and so-called 'trophic levels', which indicate the position of each functional group within the web.

Herein, the plants have a definitional trophic level of 1, as does dead organic matter ('detritus'), while exclusive plant or detritus feeders ('herbivores', 'detritivores') have a trophic level of 2. Carnivores feeding exclusively on herbivores and/or detritivores have a trophic level of 3, and so on up. Important is, however, that carnivores do not necessarily have trophic levels of exactly 3, or 4, but are more likely to have intermediate values, reflective of the mix of preys they consume. Thus, e.g., a shark that should have a trophic level of 5.0 because it feeds on groupers with a trophic level of 4.0 will end up having a trophic level of 4.5 if it feeds, equally, on a small carnivore with a trophic level of 3.0.

Because of this effect of mixed diets, top predators in marine ecosystems rarely have trophic levels in excess of 5. Indeed, such high values occur only in transient killer whales, and polar bears, which, by feeding exclusively on marine mammals (which themselves prey on piscivorous fish), can reach trophic levels much higher than those reached by fish – even the great white shark (Pauly *et al.* 1998a). Moreover, while some fish reach trophic levels in excess of 4.0, the overwhelming bulk of them have trophic levels between 2 (in herbivorous species such as anchovies, and in most commercial invertebrates) and 4 (in cod, snappers, tuna and other predators).

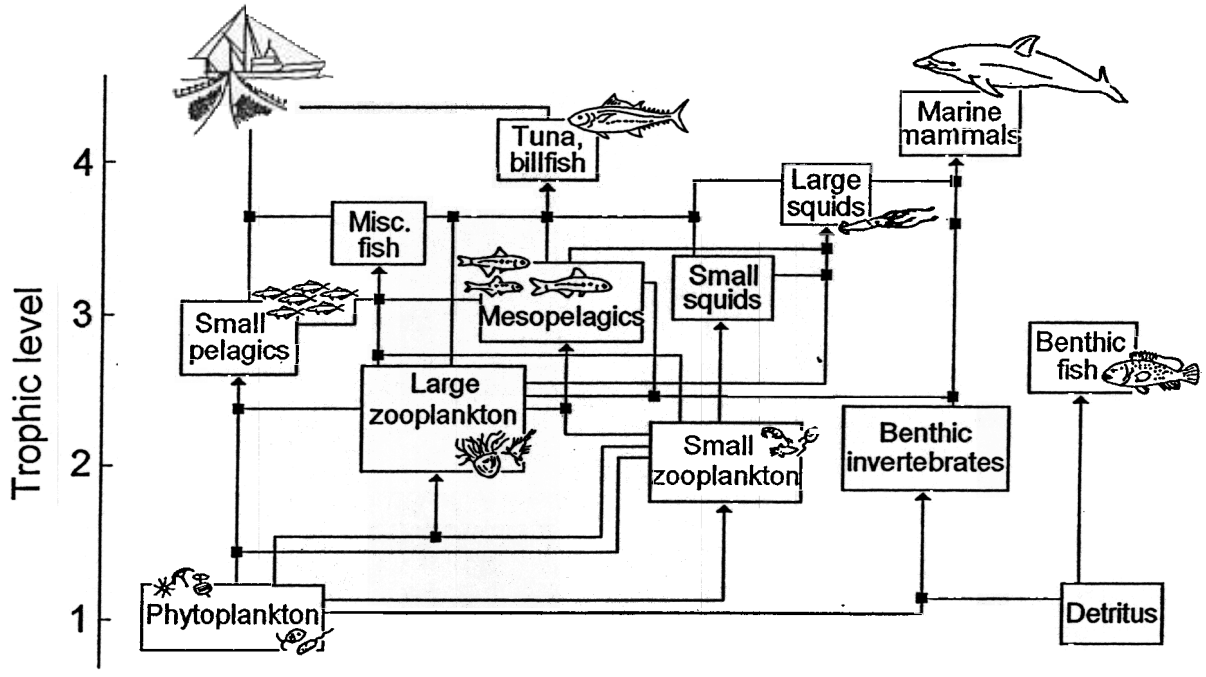


**Figure 1** Example of a simple food web, representing the oceanic part of the South China Sea (based on Pauly and Christensen 1993). Biomass fluxes were quantified using Ecopath (see also Christensen, this vol.)

This point is relevant because, as we shall sea further below, world fisheries landings increasingly consist of organisms with low trophic levels, a process now called 'Fishing down marine food webs" (Pauly *et al.* 1998a).

The demonstration of this process was based on two data sets:

1. Fisheries landings, for all areas of the world, as compiled by the Food and Agriculture Organization of the United Nations; and

2. Estimates of trophic levels for all groups in the FAO landing statistics, as obtained by ecosystem models such as illustrated in Figure 1, describing the major types of marine ecosystems, and documented in FishBase (Froese and Pauly 1998).

From these, the mean (weighted) trophic level of the fisheries landings can be straightforwardly estimated, by year and region, by averaging, after weighting the trophic level of each species group by its landings (Pauly *et al.* 1998a).

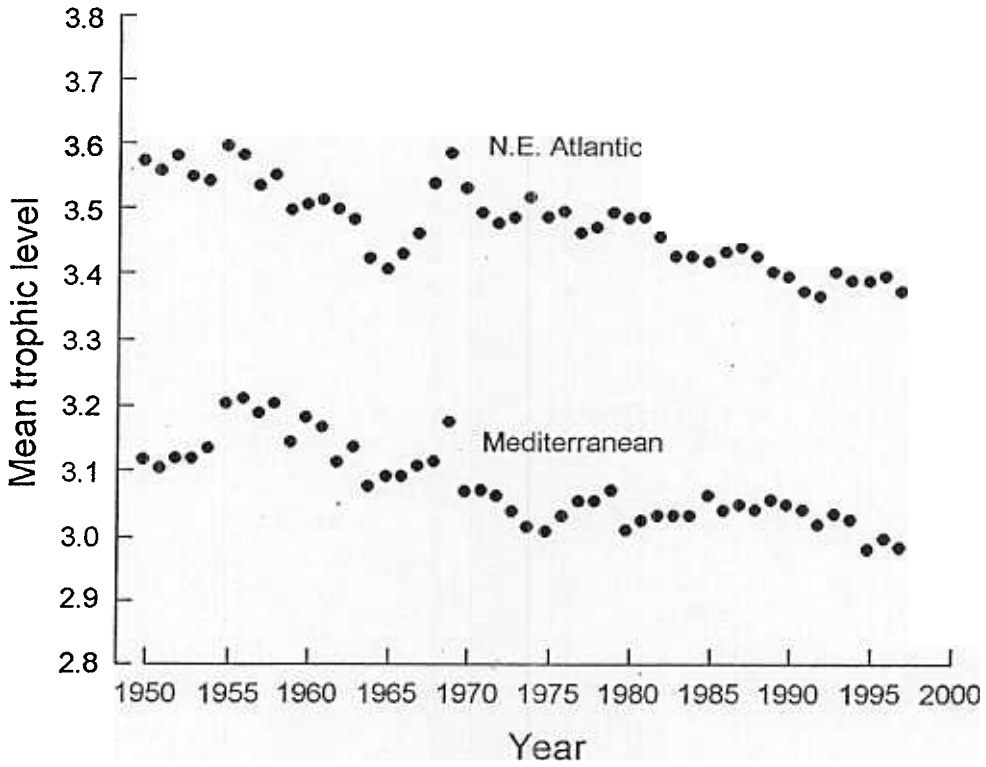


**Figure 2** Trends of mean trophic level in landings from the Eastern North Atlantic and the Mediterranean, i.e., encompassing the waters around Europe. Note that the trends in the Mediterranean started from a lower base, suggesting that high-level carnivores were depleted in earlier times (see also Stergiou, this vol.)

The results are striking: there is globally a decline in the mean trophic level of fisheries landing of about 0.1 per decade, well illustrated by the trends in FAO areas 27 and 37 (Eastern North Atlantic, and Mediterranean and Black Sea, respectively), representing European waters (see Figure 2).

In the intertropical belt, this trend is not as marked when one uses FAO regional data, which tend to be over-aggregated as far as developing countries are concerned. The effect itself (i.e., 'fishing down marine food webs') occurs, however, in developing countries as well. In Senegal for example, large predators such as the thiof (*Epinephelus aeneus*), previously a staple fish, have become very rare.

Fishing down marine food webs also occurs in Antarctica, and in freshwaters, where, in both cases, the trophic levels of the catch have strongly declined, nearly down to the herbivore level.

These results have been widely discussed in the press of several countries, and have been generally perceived as indicating a serious problem. Particularly worrisome are the usually backward-bending plots, which result when mean trophic levels are plotted against catches (Pauly *et al.* 1998a). Such plots indicate that, contrary to a widely held, if usually unstated assumption, fishing down marine food web does not lead to ever-increasing catches. Rather, below a certain trophic level – which may vary between ecosystems – further declines in trophic levels lead to *decreasing* catches.

This and related findings are presently being actively debated in the scientific literature. Given the ubiquity of 'Fishing down marine food webs', these discussions are likely to continue for a while. This report may be seen as a contribution to the debate.