Pauly, D. 2000. Commentary: fishing down marine food webs p. 195-199 In: Paul J. Harrison and T. R. Parson (eds.) Fisheries Oceanography: an integrative approach to fisheries ecology and management. Blackwell Science, Oxford.

# Commentary: Fishing Down Marine Food Webs

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## Introduction

Most readers not already committed to the arcane practices of fish 'stock assessment' (the applied part of fisheries science) will probably assume that the subject matter covered by Ware is central to fisheries management. Strangely, this is not so: stock assessments are usually performed on the basis of trends in the catches of single species, and other fisheries-derived data, without reference to the ecosystems in which these 'stocks' are embedded. This is one of the reasons why so many fisheries throughout the world tend to drift into oblivion; hence it is worth elaborating upon.

The earliest evidence of fishing by *Homo sapiens* is bone harpoons recovered along with middens and related evidence by archaeologists digging at a site in the present-day Congo (ex-Zaire) and estimated to be 90 000 years old, (Yellen *et al.*, 1995). The main species that was targeted is a now extinct, large freshwater catfish. Most probably, the fishers in question moved on to other species. This pattern of fisheries exterminating the population upon which they originally relied, then moving on to other species, has been going on since these early times (Ludwig *et al.*, 1993).

The last major step in over-fishing was the development during the Industrial Revolution of vessels with unprecedented fishing power, such as stream trawlers. Added to the substantial fishing effort of the traditional, small-scale fleet that operated inshore and tended to target juveniles, these industrial vessels, targeting stocks of adult fish further offshore, quickly reduced populations that had previously been perceived as immune to the effects of fishing.

Fisheries science emerged as a distinct branch of 'Natural History' during that period, and the first international body devoted to tackling the problem was the International Council for the Exploration of the Sea (ICES), founded in 1902. Among the first tasks ICES set for itself was the issue of over-fishing and thus it created an 'Over-fishing Committee', devoted to 'obtaining practical results', notably on 'the question of over-fishing, particularly in the Southern Part of the North Sea, and in connection with this the special study of flat-fish' (Went, 1972, p. 14). It is no coincidence that the latter quote refers to the first area/species complexes fully exposed to the impact of steam trawling (Cushing, 1988, p. 113). This led to a series of studies reconstructing the life and catch history of key species in and around the North Sea, notably the plaice, *Pleuronectes platessa* (Heincke, 1913).

## Single-species approach

Conceptually, the above work was at first guided by the observation that many of the fish caught were 'stunted' (i.e. old, but small), as frequently occurs in unfished stocks. Thus, the conventional wisdom went, fishing would 'rejuvenate' the stock and the increased growth of individual fish would compensate for the effect of moderate fishing. The practical task of fisheries scientists was thus to determine what 'moderate' fishing was (Smith, 1994).

This somewhat naïve view, which simultaneously overestimated the growth potential of fish, and underestimated the impact of modern fishing fleets, did not prevail for long among the leading scientists of the time, though it did last as part of teaching curricula long enough for this author to catch the tail end, when he was a student in Kiel, Germany, in the early 1970s.

Among practising scientists, the theory of 'thinning up stocks', as it may be called, was replaced by a series of major conceptual advances – the first catch curves and yield per recruit analyses (Baranov, 1918), and the first functional definitions of over-fishing (Russell, 1931; Graham, 1943), though this 'European approach' had at first a rather rough time among Canadian and US fisheries scientists (see comments following Dymon, 1948). These ideas led to the analytical work of Beverton and Holt (1957), which provided the conceptual basis of most contemporary stock assessments.

Beverton and Holt's (1957) 'yield-per recruit' approach was a major breakthrough as it provided, for the first time, a rationale for letting resource species realize the growth potential before they were caught (hence the regulation of mesh sizes), or conversely, to adjust fishing mortality, given a set mesh size and/or size (age) at first capture.

In practice, the mesh size and fishing mortalities used for exploiting major species in the North Sea and the other areas of the world where industrial fishing had spread, were never adjusted to the conservative levels indicated by Beverton and Holt's theory, and hence it may be argued that this theory had nothing to do with fisheries collapses now being observed throughout the world.

However, it can be shown that this theory would have failed to protect most stocks to which it was applied even if the recommendations derived from it had been adhered to, and this brings us back to the multispecies/ecosystem issues raised in Ware's chapter.

## The multispecies problem

The transition from single-species assessments to ecosystem-based management was gradual and involved, in many cases, 'multispecies' assessment as an intermediate step, considering a limited number of species (reviews in Gulland, 1988).

However, Pope (1979) in a remarkable study, unfortunately published in the grey literature, pointed out the key problem in attempts to optimize the exploitation of multispecies assemblages. This is the fact that fisheries, especially modern, largely unselective bottom trawl fisheries, while technically able to control the overall mortality they exert, cannot control the relative strength of the fishing mortality inflicted onto the different components of a multispecies stock.

In other words, in a commercial fishery not using a highly selective gear, 'technological interactions' will always cause some species to be subjected to excessive, non-sustainable levels of mortality. The result is that some species will decrease to very low levels, and go locally extinct (Pitcher, 1998).

Excess fishing mortality, leading to low biomass levels, in single-species fisheries, implies – at least in theory – that fishing becomes unprofitable. This should result in a reduction of fishing effort, and hence fishing effort, at least in principle, should self-regulate. However, this does not happen in practice, because of the massive amounts of subsidies that governments provide to fisheries, especially to large-scale operations (Garcia and Newton, 1997), and differential fishing costs within heterogeneous fleets, two issues not further discussed here.

In multispecies fisheries, the self-regulatory element hypothesized above does not occur even in principle, because the fishery that continues to exploit a much-depleted species (e.g. of large fish in a shrimp fishery) does not target all the fish it kills. Hence the enormous amount of discards presently generated, is estimated to be about 30 million tons per year ($\frac{1}{4}$ of the world catch) in a recent FAO-sponsored study (Alverson *et al.*, 1994).

It is no accident that Pope's seminal study was commissioned by a body devoted to the study and management of a fishery in that part of the world with the most diverse marine fauna (the South China Sea and other Southeast Asian seas). Rather, it reflects the perception, prevailing in the 1970s and 1980s that multispecies fisheries was an issue predominantly associated with tropical developing countries. Correspondingly, most research emphasis at that time in developed countries was devoted to refinements of approaches derived from Beverton and Holts' yield-per-recruit analysis (notably 'virtual' population analysis'), all single-species in nature.

Pope (1979), while considering what he called 'technological interactions' (see above), explicitly excluded biological interactions (i.e., the fact that, among other things, fish eat each other). He did so in order to make his study tractable. However, biological interactions, especially feeding interactions may be even more important than technological interactions.

First of all, there is the problem that you cannot exploit both a fish species and its prey species, and expect both to be exploited optimally in terms of their growth and mortality schedule, i.e. in terms of the optimum that would be estimated from single-species analytical models. This seems trivial, yet we do not have governance arrangements for any fishery in the world focused on predatory species that explicitly aim to reduce fishing on the prey species, e.g. by compensating those who would target the latter (or conversely for exploitation of prey species).

Thus, both groups of species, the predators and the prey species, are exploited simultaneously and strongly, leading to: (1) the technological interactions alluded to above, (2) biological interactions, and (3) a gradual shift of species abundance in the ecosystem, and thus in fishery catches, our next subject.

## From species changes to fishing down marine food webs

Changes in species dominance in ecosystems, and hence in fisheries catches have been known to occur for decades, and indeed, not all of them are due to fishing (Daan, 1980). However, comparative analyses of a large number of cases of species changes in different oceans at different latitudes, show that these changes in the last two decades share a common, worrisome pattern: almost everywhere, large, long-lived fish high in the food web tend to decline, both in the catches and in the ecosystem and they are replaced by small fast-growing fish from lower trophic levels (Pauly *et al.* 1998; Fig. 7.21).

This process, now known as 'fishing down marine food webs' (though it also occurs in exploited freshwater systems) would be acceptable – at least to some – if, as is usually expected, the decline of mean trophic levels was accompanied by a corresponding increase in catches. However, while such an increase often occurs when 'fishing down' is initiated, catches soon stop increasing and all one obtains is decreasing fish sizes, and more invertebrates. Thus, the long-term outcome of the present trends is that global fisheries may end up with mainly zooplankton left to harvest.

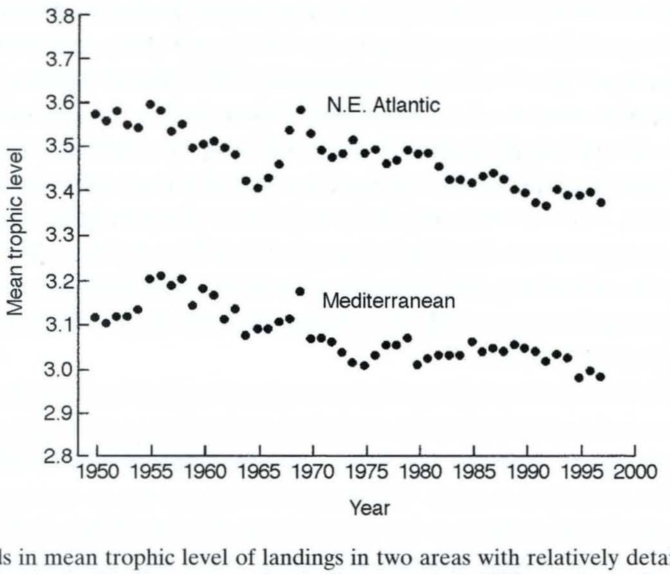


**Fig. 7.21** Trends in mean trophic level of landings in two areas with relatively detailed fisheries statistics. Note that in the Mediterranean, the decline started, in 1950, at a lower baseline, and is now heading toward catches dominated by small pelagic herbivores. Similar trends can be shown to occur in most parts of the world, given accurate and detailed fisheries (Pauly *et al.*, 1998).

## A new rationale for putting fisheries in an ecosystems context

I believe that the existence of strong trends such as the one briefly presented above provides a strong rationale for modelling efforts such as reviewed by Ware. Thus, while it is true, as stressed by Denman (pp. 200–206, following), that modelling of marine ecosystems will never allow precise predictions of future states of individual components, it is equally true that the 'fishing down' trends described above, and related phenomena, require future modelling for their further interpretation. Moreover, halting such trends will require interventions – such as marine protected areas (MPAs) – whose broad effects will require analysis through ecosystem models.

Research by Alcala and his associates in the Philippines (Alcala, 1981; Alcala and Russ, 1990), by Ballantine (1991) in New Zealand, and many others has led to an emerging consensus (see Roberts *et al.*, 1995; NRC 1999) that MPAs, as Bohnsack (1993) put it, 'enhance fisheries, reduce conflicts and protect resources'. However, this consensus does not include many fisheries scientists working in the government laboratories in Europe and North America and conducting the research underlying the management of commercial fisheries. Indeed, there is among these colleagues an almost visceral rejection of MPAs as a fisheries management tool (Roberts 1999), notwithstanding the abysmal record of the other management tools (mesh size, effort and catch regulations) so far used.

Spatially structured ecosystem models (Chapter 7) will help here, if only to frame hypotheses regarding the benefits that may be expected from MPAs (see Walters *et al.*, 1998). Here again, high precision regarding the future state of individual groups will not be required. Rather, what will be required are estimates of broad ranges of costs and benefits, across all major groups in a system, for situations with and without MPAs, something which several of the models reviewed in Ware's contribution can provide quite straightforwardly.

This will rectify the anomaly noted in the Introduction, that ecosystem modelling is presently at the periphery of fisheries research, and will indeed put the ecosystem approaches reviewed in Ware's chapter at the centre of fisheries science, where they should have been from the outset.