STERGIOU K.I. 2005. Fisheries impact on trophic levels: long-term trends in Hellenic waters. pp. 326-329. In: Papathanassiou E., A. Zenetos (eds) State of the Hellenic marine environment, Hellenic Centre for Marine Research, Athens, Greece.

VIII.5. FISHERIES IMPACT ON TROPHIC LEVELS: LONG-TERM TRENDS IN HELLENIC WATERS

Overfishing, that is the removal of marine organisms at a rate much faster than that supported by the ecosystems in which these organisms are embedded, has been documented for both coastal and open-sea ecosystems by many research groups (e.g. PAULY *et al.*, 2002, MYERS & WORM, 2003, CHRISTENSEN *et al.,* 2003). Overfishing dramatically impacts all levels of biological organisation of marine life: populations, communities and ecosystems.

Among the various effects of overfishing, those related to the trophic structure and thus the energy flow within marine ecosystems have received particular attention in recent years because of the pioneering work of Pauly and his co-workers from the Fisheries Centre of the University of British Columbia (Canada). This group used the fisheries catch statistics published annually by the U.N. Food and Agriculture Organisation (FAO) and the trophic level (for its definition/estimation, see Box 1 in Chapter VII.2), of all species or groups of species participating in the catches. They showed that the mean trophic level of the catches declined by about 0.5-1 trophic level during the last 50 years (PAULY *et al.*, 1998). Such a decline was generally true both on a global scale (i.e., when considering the global marine catches) and on an ocean-specific scale (i.e., for each of the different FAO subareas of the Atlantic, Indian and Pacific Oceans, and the Mediterranean-Black Seas). For the definition of trophic level readers are addressed to Chapter VII.2 in this volume.

Ecologically, this decline in mean trophic level can be explained based on the relationships between fishing, sizes of organisms fished and their trophic levels. In general, fishing selectively removes the largest organisms and this is true of both between- and within-species. Since trophic levels in marine organisms generally increase with size, again both between- and within-species, intense fishing lowers the relative catch contribution of large-sized organisms, positioned high in the food web. As a result, fisheries catches are progressively dominated by small-sized fishes (i.e., the mean trophic level of the catches declines with time).

The approach of Pauly's group had an important impact on fisheries science and became known as the **'fishing down the marine food web'** process. Although CADDY and his co-workers (1998) raised various sources of bias that might have affected the results of Pauly's group, all of these concerns were later fully addressed (for a detailed account see: PAULY & PALOMARES, 2005). Furthermore, 'fishing down' has been also verified by other scientists on smaller, regional scales (e.g. North Sea, Celtic Sea, Icelandic waters, Canadian waters, Cuban waters and the Mediterranean Sea; PAULY & PALOMARES 2005).

For the Hellenic Seas, a preliminary analysis (CIESM, 2000) showed that in many areas of the Aegean Sea (i.e., the Saronikos Gulf, the Thermaikos Gulf, the Sea of Thraki and the southern Aegean) the mean trophic level of the catches decreased during recent years. In contrast, 'fishing down' was less pronounced in the Hellenic part of the Ionian Sea. This preliminary analysis was based on the catches of fish, cephalopods and crustaceans, reported by the National Statistical Service of Hellas for 1964-1997 and preliminary gross estimates of the trophic levels of the species making up these catches. In this report, the catch time-series is extended back to 1950, using the FAO data and restricted to fish species only.

DATA AND METHODS USED

The Hellenic catches of all fish species (or group of species, henceforth called species) from the FAO fishing subarea Mediterranean-Black Sea (FAO subarea 37) during 1950-2001 were extracted from the FAO global fisheries capture database using the software Fishstat Plus (version 2.30; both catches and software downloadable from

www.fao.org). Firstly, Hellenic fish catches were aggregated by four trophic level classes, i.e., 2-3, 3-3.5, 3.5-4 and 4-4.5, and plotted against time. Secondly, the mean trophic level of the catches of all fish and of fish with trophic levels higher than 3.5 and 3.75, and the corresponding 'Fisheries in Balance' (FiB) indices were also computed and plotted against time.

All someone needs to estimate the mean trophic level of the catches derived from a marine region are the individual catch weight and trophic level values of all species participating in the local catches. In this case, the mean trophic level of the catch in a particular year is estimated by multiplying the trophic level of each species by its catch weight; add these across all species participating in the catches and divide this by the total catch of all species in this particular year (PAULY *et al.*, 1998).

The FiB index is used to track the 'fishing down the food web' process (PAULY & PALOMARES, 2005). Given a time-series of catches and their mean trophic levels, the FiB index is calculated for each year of a time-series, as the ratio, at a log scale, between: (a) the total annual catch, multiplied by the energy transfer efficiency between trophic levels (an ecosystem property, having a mean value of 10%) after the latter has been raised to the mean trophic level of the catch and (b) the estimate of (a) above for the first year of a time-series as a reference (PAULY & PALOMARES, 2005). The FiB index (PAULY & PALOMARES, 2005): (a) attains a value of 0 for the first year of the series; (b) does not vary during periods in which trophic level and catches change in opposite directions; and (c) increasing or decreasing FiB values indicate a geographic expansion or contraction (or collapse) of the underlying fishery, respectively.

The mean trophic levels of the catches and the FiB index for 1950-2001 were estimated using the trophic level values from STERGIOU & KARPOUZI (2002) supplemented, when necessary, with trophic level values from FishBase (www.fishbase.org).

CHANGE IN TROPHIC LEVEL OF CATCHES

Fish Catches per Trophic Level Class

Fish with trophic levels ranging between 3 and 3.5 dominated the catches by far, contributing 62% to the mean total catch during 1950-2001. They were mainly represented by the small pelagics anchovy and sardine, followed by the Mediterranean horse mackerel, picarels, chub mackerel, red mullet and pandora. The total catches of fish with trophic levels from 3.5 to 4 contributed 18% to the mean total and were mainly composed of blue whiting, Atlantic mackerel, Atlantic horse mackerel, rays, scorpionfish and other species groups. Finally, the species groups with the lowest and highest trophic levels (i.e., 2-3 and 4-4.5, respectively) each contributed about 10 % to the mean total. The catches of the first group (2-3) were composed of three species only, bogue, salema and mullets, whereas those of the second group were dominated by large demersal fish, such as hake and groupers, and large pelagic fish, such as bonito, swordfish and tunas.

The catches of these four groups rapidly increased from the early 1950s to a peak in 1994 followed by a decline (Figure VIII.26). The ratio between the maximum and minimum catch during 1950-2001 was higher for the 3.5-4 trophic level group (=11) when compared with the remaining ones (9, 4 and 8 for trophic level groups 2-3, 3-3.5 and greater than 4, respectively).

'Fishing down' and the FiB index

Figure VIII.27 shows the mean trophic level of the total catches during 1950-2001, from which it becomes evident that it smoothly declined by 0.1 trophic level during 1950-1980 and increased again during the years following 1980. The increase in the second period clearly resulted from the fact that the increase in the catches of fishes having trophic levels 3.5-4 and, to a lesser extent, 4-4.5, more than compensated for the increase in the catches of the lower trophic level fish (Figure VIII.26). Indeed, the picture changes when one considers only high trophic level fish; in this case a declining trend with time becomes apparent during 1950-2001, being steeper in the case of trophic levels greater than 4 (Figure VIII.27).

Figure VIII.28 shows the variations in the FiB index during 1950-2001. For all fish species, FiB fluctuated around zero during the period from 1950 to the early 1970s, followed by a linear increase to a peak in 1994 and a decline thereafter. This was also the case for fish with trophic levels greater than 3.5 (Figure VIII.28). The increase in the FiB index indicates a general 'expansion' of the Hellenic fisheries, which indeed has taken place

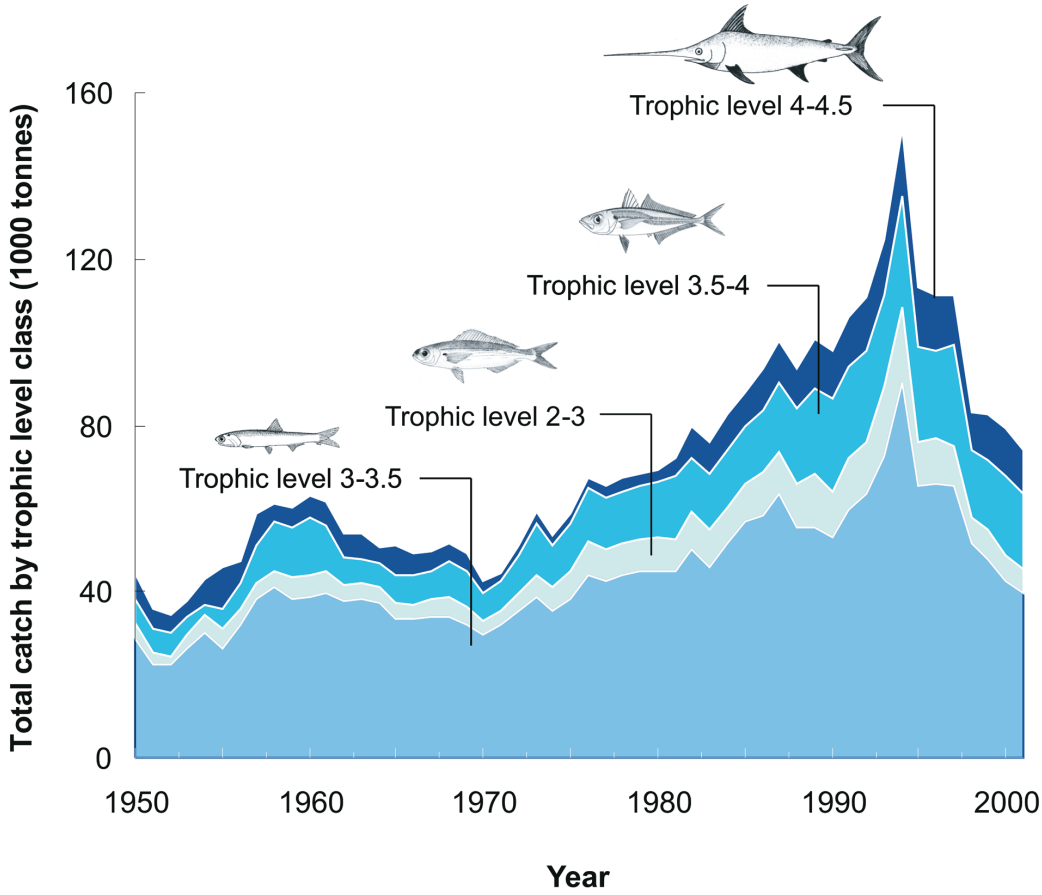

Figure VIII.26: *Hellenic waters, 1950-2001. Long-term changes in fish catches aggregated by four trophic level classes.*

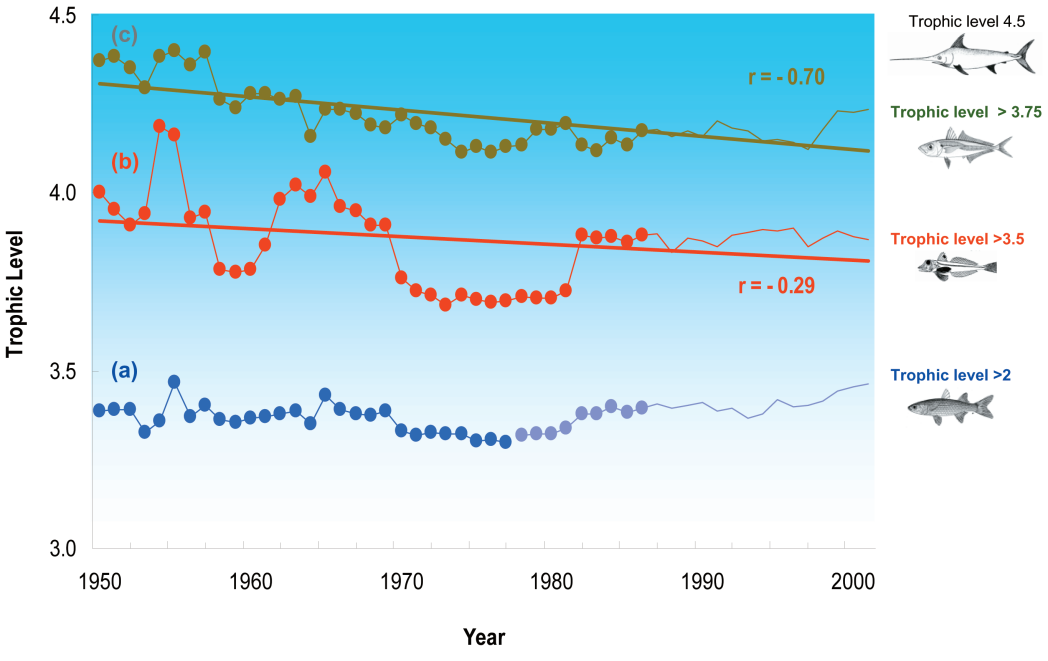

Figure VIII. 27: *Hellenic waters, 1950-2001. Long-term trends in the mean trophic level of catches for all fish species (trophic levels >2) and for fish species having trophic levels >3.5 and >3.75.*

during the 1980s and early 1990s for two reasons; the modernisation of the fleet and the effect of man-made eutrophication on the productivity of coastal waters.

The modernisation of small- and large-scale fishing fleets (i.e., larger boats, of higher tonnage and engine horsepower, improved fishing gears, use of high-technology equipment; STERGIOU *et al.*, 1997) led to the expansion of fishing in open-sea areas, previously largely inaccessible by fishing vessels because of strong winds (e.g., in southern waters) and in deep water areas. As a result, new 'resources' started to be exploited, mostly at high trophic levels (i.e., greater than 3.5). These new resources refer to both species not previously exploited as well as to the large, mature individuals of many previously-exploited species (e.g., hake), which by inhabiting deep waters were inaccessible by trawlers (i.e., deep water areas acted as natural 'no-take' zones).

In addition, the general increase in man-made eutrophication of Hellenic and Mediterranean waters during the last decades (e.g. CADDY *et al.,* 1998) boosted productivity in coastal waters. This increased fisheries catches across all trophic levels and further contributed to the 'expansion' of the Hellenic fisheries.

Thus, fish from areas previously not exploited and fish 'generated' by eutrophication formed the basis of the Hellenic fisheries during 1980-1995, replacing the fish which 'fishing down' has removed. The use of the FiB index revealed this effect. However, the misleadingly good consequences of technology and eutrophication have faded away, judging from the recent, downhill catches across all trophic levels (Figure VIII. 26).

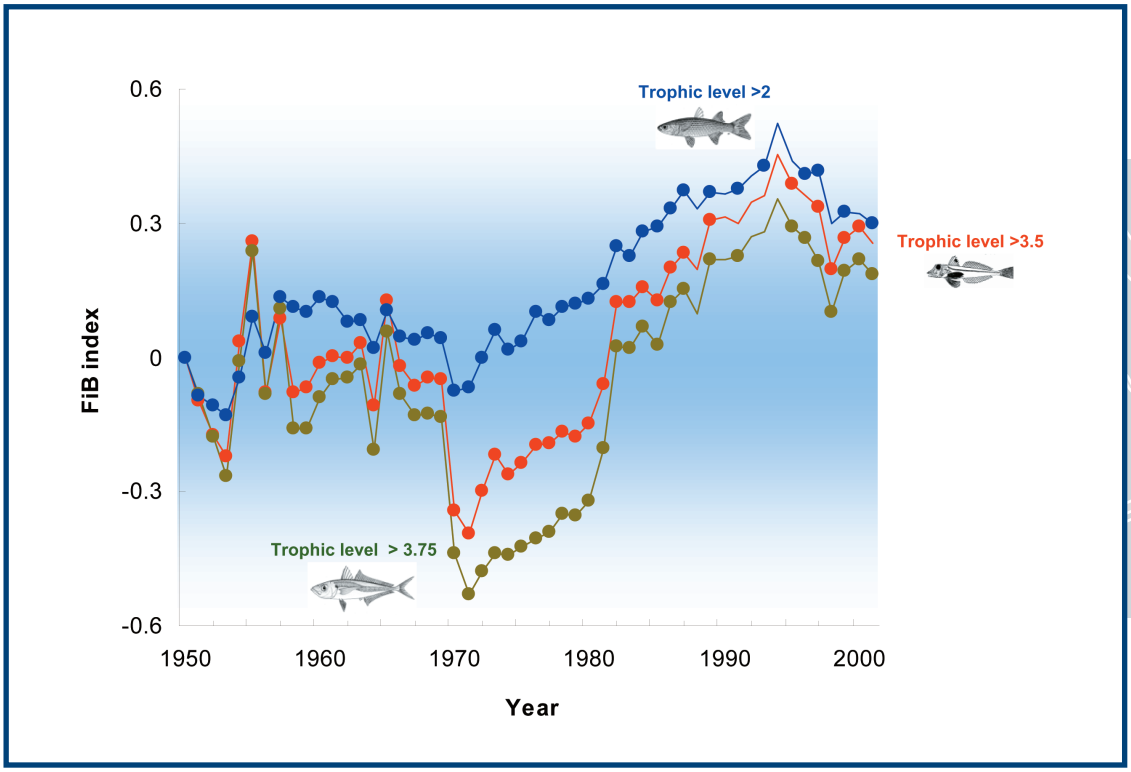

Figure VIII.28: *Hellenic waters, 1950-2001. Long-term trends in the FIB index of the catches of all fish species (trophic levels >2) and of fish species having trophic levels >3.5 and >3.75.*