Fishing down the marine food webs in the Hellenic seas

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INTRODUCTION

Fishing has important effects on marine ecosystems both at the level of the life-history of the individual species (*e.g.* decreasing mean body size and mean size/age at maturity, changing sex ratios, and decreasing population reproductive potential: *e.g.* Jennings *et al.* 1998; Stergiou, 1999) and at the ecosystem level (*e.g.* altering the structure and heterogeneity of benthic habitat, changing species composition and diversity, decreasing stock abundance, changing predation and competition rates, changing trophic structures and energy flows: Pauly and Christensen 1995; Pauly *et al.* 1998a, 2000a; Stergiou 1999; Tudela, this volume; Harmelin-Vivien, this volume).

Among the latter effects, those concerning the trophic structure and energy flow of marine ecosystems are very important. Indeed fisheries landings, including by-catch, require about 24-35% of the global marine primary production over the continental shelf and major upwelling areas of the world ocean, a fraction that is much higher than previously thought (Pauly and Christensen, 1995). Such a large-scale removal is not without any effects on the structure of food webs. Thus Pauly *et al.* (1998a, 2000a) clearly showed that the mean trophic level of the fisheries landings in the last 45 years has decreased steadily both at the global scale (total marine and freshwater landings) and at the regional, ocean-specific, scale (i.e. Atlantic, Pacific, Mediterranean), with few exceptions. Pauly *et al.* (2000a) maintained further that such a decline might be even faster than documented, because of arguments that relate ontogenic changes in feeding of individual species with trophic levels. The approach of Pauly *et al.* (1998a), currently known as the "fishing down the food web" theory (FDFW), seems to be a promising tool for identifying whether the fishery in a particular region is sustainable or not. Although a debate was raised (Caddy *et al.* 1998) on four sources of bias that may have affected Pauly's *et al.* (1998a) results, all these methodological issues have been recently addressed (i.e., using the abundance of species groups in landings as proxy for their relative abundance in the ecosystems: Pauly *et al.*, 1998b; ontogenic, taxonomic and bottom-up effects: Pauly 2000a, Pauly and Palomares, this volume). The FDFW hypothesis triggered fisheries scientists to start searching for similar patterns at the local scale. In this work, we test the hypothesis that the mean trophic level of the landings in the Hellenic seas (i.e. Ionian and Aegean) has declined during the last 34 years, using the available landing data for the period 1964-1997.

SOURCES OF DATA

The fishing fleet operating in the Hellenic seas includes (Stergiou *et al.*, 1997): (a) trawlers operating in open-sea waters, (b) purse seiners operating in open-sea and coastal waters, (c) "mixed vessels" operating in waters both as trawlers, mainly in the wintertime, and purse sein-

ers, mainly in the summertime, (d) beach seiners operating along the coasts, and (e) "other coastal boats" (including small ring netters, drifters, liners, etc.) operating along the coasts. The National Statistical Service of Hellas records the Hellenic landings since January 1964 (Stergiou *et al.*, 1997). For a better evaluation of the available data, Hellenic waters have been divided into statistical fishing sub-areas (Fig. 1).

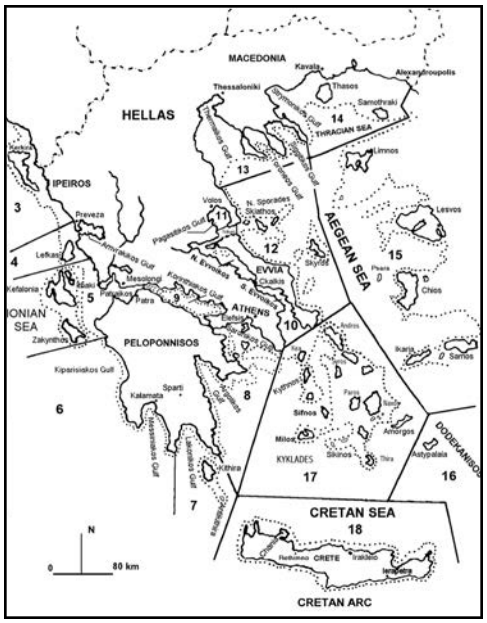

Fig. 1. Map showing 16 Hellenic fishing sub-areas. The dotted line represents the 200 m isobath.

Catch data are collected directly from a sample of fishing vessels that are surveyed by local customs authorities (stratified random sampling). For each vessel surveyed, a statistical questionnaire is completed showing the quantities of each major species caught during the previous month for the actual periods of activity. It is noteworthy that since 1969 the local customs authorities do not record the catches of the smaller inshore ring netters, drifters and liners (i.e. "other coastal boats" with engine horsepower of less than 20 HP). For the period 1964-1981, separate catch statistics are available for 23 species only (or group of species; henceforth called species) whereas for the years following 1981 separate catch statistics have been available for 66 species of commercially important fishes, cephalopods and crustaceans. Although the NSSH data suffer from various biases, which are higher for inshore fisheries and the degree of bias can not be easily estimated, they are the best figures available with respect to: (a) length of time, (b) spatial and temporal resolution, (c) consistency and degree of subjectivity in data collection, and (d) statistical design of data collection (Stergiou *et al.*, 1997).

The trophic level values (TL; for definition of TL as measurable entity, see Pauly and Palomares, this volume) of all species recorded by NSSH were taken from Pauly *et al.* (1998a; available on the Internet at www.fisheries.com). For each sub-area, the mean mTLi for each year i was estimated by multiplying the landings (Li) by the trophic levels of the individual species j, then taking a weighted mean: $mTL_i = (\Sigma_{ij} TL_{ij} L_{ij})/(\Sigma L_{ij})$ (Pauly *et al.* 1998a; Pauly and Palomares, this volume).

RESULTS AND DISCUSSION

For most sub-areas (i.e. 3, 4, 6, 7, 9 10, 13-15, 17 and 18), total landings steadily increased from 1964 up to the early-mid 1990s and then declined sharply (figures not shown here). The same was true of sub-area 16, except for an earlier peak in the 1980s. For sub-areas 5, 8 and 12, total landings steadily increased from 1964 to 1997 and those of sub-area 11 exhibited peaks in the mid 1970s. It is noteworthy that the engine-horsepower/boat and tonnage/boat ratios also sharply increased from 1964 to 1997 for all component fisheries, with the exception of the "other coastal boats" fishery for which the rate of increase was much smoother (Stergiou *et al.*, 1997; Stergiou, unpubl. data). This clearly indicates the modernization of the Hellenic fishing fleet, with older boats being replaced by new ones of higher capacity (larger tonnage and engine HP), mainly because of EU subsidies.

The mTL of the landings during 1964-1997 for the 16 fishing sub-areas is shown in Figure 2. In general, mTL fluctuated greatly with time. In addition, mTL was significantly (t-test, $P<0.05$) lower in 1964-1981 when compared to 1982-1997 for the majority of fishing sub-areas, a fact that is most probably attributed to the higher taxonomic resolution of the catches for the latter period (Pauly and Palomares, this volume).

The mTL of the landings declined significantly with time [i.e. the slope of the mTL-time regressions being significantly ($P<0.05$) different from zero and negative] for both study periods only for sub-areas 16 to 18 (southern Aegean Sea) and the decline was of the order of 0.1 TLunits (Fig. 2). It also declined significantly ($P<0.05$) during 1964-1981 for sub-area 7 (by about 0.1 TL

unit) and during 1982-1997 for sub-areas 4 and 10 (by about 0.3 TL units). All remaining sub-areas showed no clear trends in the mTL changes over time. Thus, some sub-areas exhibited an increasing trend in mTL either during 1982-1997 (*e.g.* sub-areas 7, 12 and 15) or during both periods (*e.g.* sub-area 9) (Fig. 2) whereas others exhibited no trend (*e.g.* sub-areas 5, 8, 14). Yet, during the last decade, mTL sharply declined by 0.1 to 0.4 TL units in all sub-areas with the exception of sub-areas 7, 11, 12 and 15.

It is noteworthy that the mTL of the landings of the three most important sub-areas of the Hellenic Seas, namely sub-area 8 (Saronikos Gulf) and sub-areas 13 and 14 (North Aegean Sea), which make up more than 45% of the total Hellenic landings (Stergiou *et al.*, 1997), also showed no evidence of the FDFW effect (Fig. 2). However, anchovy and sardine generally dominate the landings of these sub-areas, making up more than 30-40% of the total, depending on the sub-area

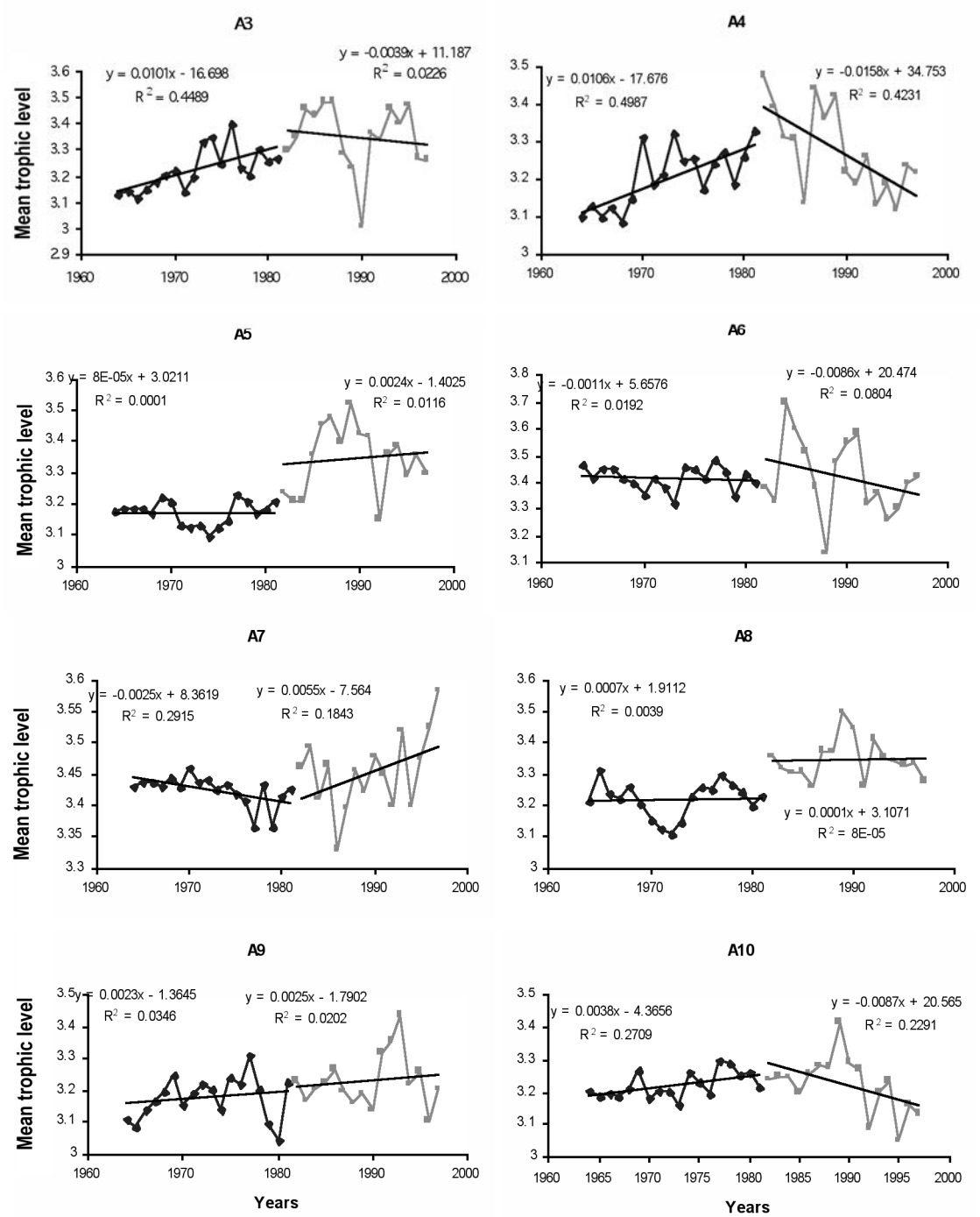

Fig. 2 **a.** Mean trophic level of the landings in 16 fishing sub-areaS (A3 to A18) of the Hellenic seas during 1964-1997 (first part).

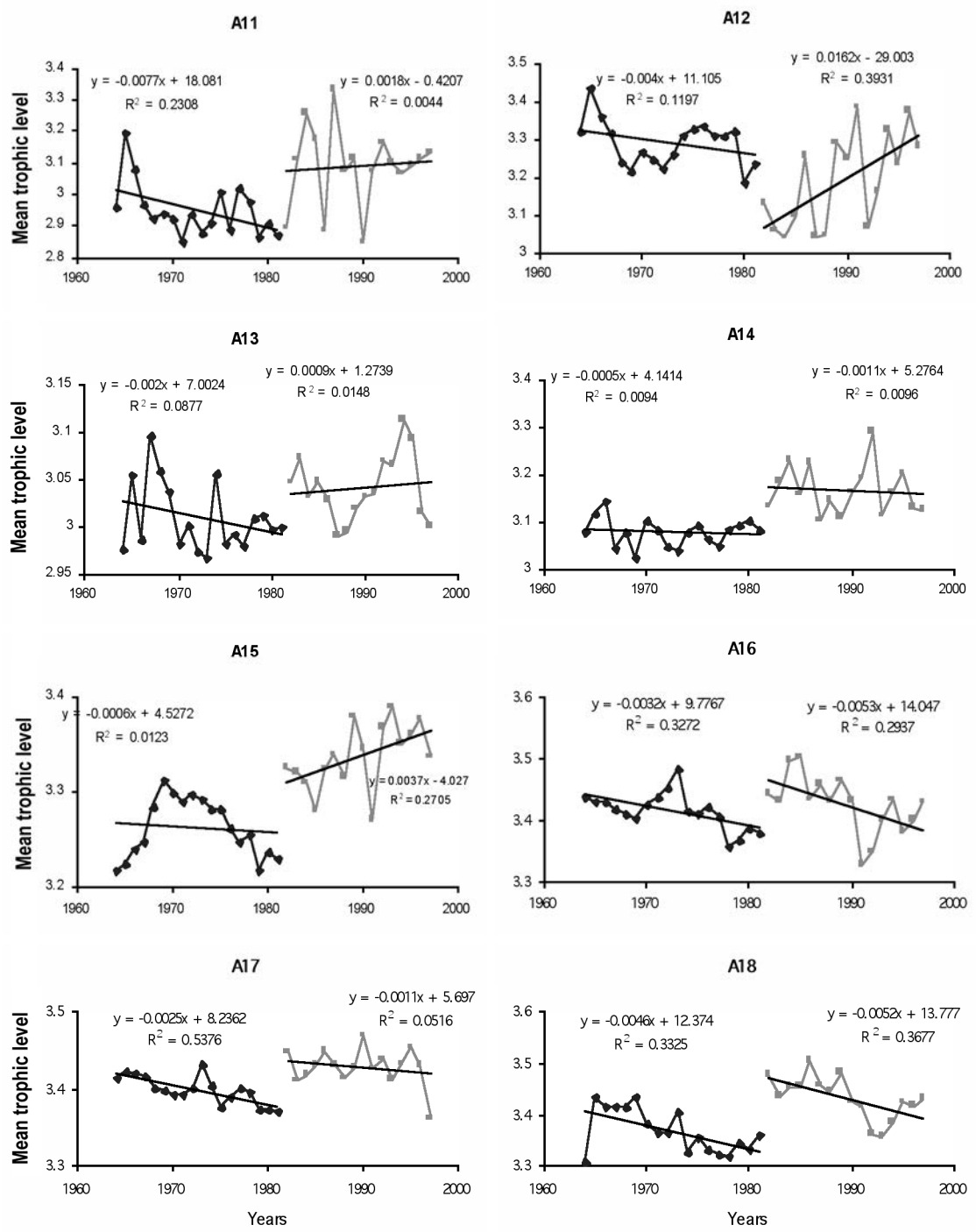

Fig. 2 **b**. second part.

(Stergiou *et al.*, 1997). These two small pelagic species generally undergo large fluctuations in the landings because of climatic and/or economic factors (*e.g.* Stergiou and Christou, 1996; Stergiou and Lascaratos, 1997; Stergiou *et al.*, 1997), a fact leading to large year-to-year fluctuations in mTL, which may mask any other long-term trends. Indeed when the anchovy and sardine landings were not taken into account for the estimations of mTL (figures not shown here), mTL in all three sub-areas declined significantly with time ($P<0.05$) during both study periods by about 0.1 TL unit, except for sub-area 8 in 1964-1981. The same was also true of sub-area 11, for which mTL declined by almost 0.2 units during 1982-1997, as well as for sub-areas 12 and 15 during 1982-1997, although in the latter two sub-areas the trend was not significant ($P>0.5$).

During the last years the mean body size of anchovy and sardine has decreased in the North Aegean Sea (Stergiou, unpubl. data; Voulgaridou and Stergiou, 2000). In addition, the majority

of the demersal fishes in the Hellenic seas suffer from growth overfishing, with commercial landings consisting mainly of young, immature individuals (Stergiou *et al.*, 1997). Such changes, which cannot be captured by the present analysis, would strengthen the observed trends (or even reveal unobserved ones), because smaller individuals generally feed at lower trophic levels (Pauly *et al.* 1998a, 2000a; Pauly and Palomares, this volume).

The results show that in the main part of the Aegean Sea (i.e. sub-areas 8, 13, 14 and 15-18) the mTL of the landings has decreased during the last years. This trend, which seems to be more pronounced during the last years (Fig. 2), indicates that the Aegean fisheries resources are not sustainable, a fact found in agreement with the results of both field and catch-effort studies (Stergiou *et al.*, 1997). In contrast, the FDFW effect was less pronounced in the Ionian Sea (i.e. sub-areas 3 to 7), although in sub-areas 4 to 6 the mTL of the landings declined during the last years. Such a difference between the two seas may be attributed to: (a) the low level of the Ionian landings, about 10-13% of the grand total; (b) the smaller accuracy of the Ionian when compared to the Aegean data because of the predominance of the artisanal fishery (mainly in sub-areas 6, 7 and 9, which are almost exclusively fished by small-scale fishing gears); (c) the fact that Hellenic landings might not be representative of the Ionian situation because the Hellenic part of the Ionian Sea comprises part of a larger area in which the existing stocks are fished by a number of other nations (*e.g.* Albania, Italy), with the Hellenic landings representing about 7% of the total Ionian ones (Stergiou and Pollard, 1994; Stergiou *et al.*, 1997); and (d) a potential expansion of the Ionian fishery into new fishing grounds. We are still working on combining the two time series of landings (i.e. 1964-1981, 1982-1997) and interpreting the combined mTL-catch plots for all 16 sub-areas (an example is presented in Fig. 3) as well as on estimating Pauly's FIB index (Pauly *et al.*, 2000b) for further evaluating the FDFW effects in Hellenic waters.

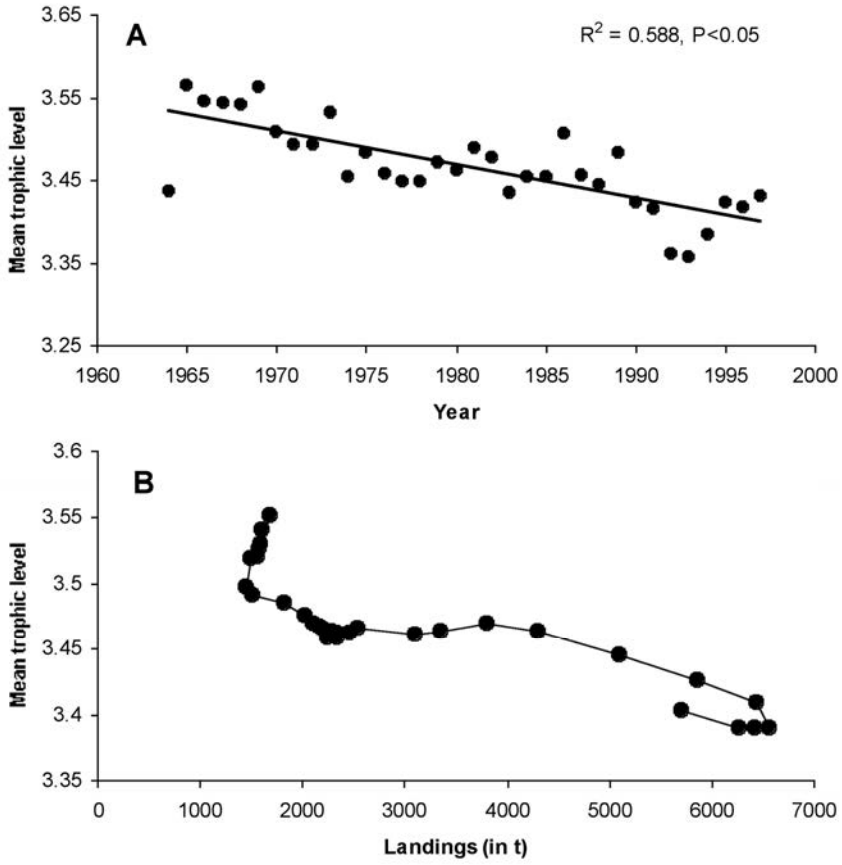

Fig.3. **(A)** Mean trophic level, mTL, of landings in fishing subarea 18, reconstructed so that to take into account the higher taxonomic resolution of landings in 1982-1997 when compared to 1964-1981; reconstruction was done by adding the difference in the mean mTL of landings for the two periods to the mTL of the landings during 1964-1981); and **(B)** relationship between the 5-year running means of mTL of landings and of landings for fishing subarea 18.

Fisheries management in Hellenic waters is practiced through static, technical measures in a non-adaptive, and certainly far from being precautionary, way. The inadequacy of the technical regulations currently in force is justified by the fact that, despite the reinforcement of such measures, demersal and inshore fisheries resources are currently overfished. Thus, Stergiou *et al.* (1997) have suggested that such measures should be either replaced or complemented by Marine Protected Area (MPA) which represent the extreme case of the precautionary approach. MPAs protect marine biodiversity, decrease the trend for heavy evolutionary fishing selection for earlier maturity and reproduction and smaller adult fish size, and hedge against uncertainties, errors in estimations and biases (see Lauck *et al.*, 1998, and references therein), thus maintaining the trophic structure of marine ecosystems.