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Exploitation trends of the Mediterranean and Black Sea fisheries

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The exploitation trends of Mediterranean and Black Sea fisheries stocks were examined using the total annual catches, the variability of the mean trophic level of the catch and fishing-in-balance index for the period 1970-2010. Overall catches increased rapidly to their maximum levels by the late 1980s and then declined and remained rather stable at around 75% of their highest levels. The mean trophic level of the catches followed a similar pattern to the overall catches with constant (except for 2005-2007) but steady decline since the late 1980s. The annual catches of 2636 stocks were also analysed for the period 1970-2010 and classified into exploitation categories according to the catch-based method of stock classification. In 2010, about 22% of the stocks were depleted, 40% were overexploited, 24% were fully exploited while undeveloped/developing fisheries were confined to 14%. All analyses indicate that the Mediterranean and Black Sea fisheries are gradually contracting to unsustainable levels.

Key words: marine catches, trophodynamics, overfishing, Mediterranean Sea, Black Sea

INTRODUCTION

Contrary to the north Atlantic for which long-term time series of fisheries catch data are available, at least for some species of high commercial interest (e.g. herring *Clupea harengus*, cod *Gadus morhua*: OJAVEER *et al.*, 2007; plaice *Pleuronectes platessa*: CARDINALE *et al.*, 2011), and stock assessments that may extend back to 1800 (RICARD *et al.*, 2012), such data for the Mediterranean and the Black Seas are scarce and sporadically collected (PILLING *et al.*, 2008; STERGIOU & TSIKLIRAS, 2011). Catch (=landings for the purposes of this work) data for most Mediterranean and the Black Sea stocks are available since 1950 through the Food and Agricultural Organization (FAO) and since the 1970 through the General Fisheries Commission for the Mediterranean (GFCM) records (in some cases, historical catches are available: MOUTOPOULOS & STERGIOU, 2011), while stock assessments and surveys usually concern a limited number of species and are routinely performed within the framework of international projects (e.g. less than four stock assessments from the Mediterranean and the Black Seas are included in the RAM Legacy Stock Assessment Database: RICARD *et al.*, 2012). The scarcity of catch and stock assessment data is more pronounced at the eastern and southern parts of the Mediterranean (STERGIOU & TSIKLIRAS, 2006), and for that reason, several Mediterranean areas have been characterized as fisheries data poor areas (PILLING *et al.*, 2008).

Official fisheries catch statistics (such as those recorded by FAO and GFCM) and reconstructed catches available from other sources (e.g. Sea Around Us Project: CHASSOT *et al.*, 2010) are considered proxies of stock size and have been widely used to uncover patterns and trends in fisheries (CHRISTENSEN *et al.*, 2003; MYERS & WORM, 2003; PINNEGAR *et al.*, 2003; ZWOLINSLI & DEMER, 2012; PAULY *et al.,* 2013; TSIKLIRAS *et al.*, 2013). Since catch statistics may be affected by fisher's behaviour, market forces and fisheries regulations (MAUNDER & PUNT, 2004), stock assessments have been proposed as a more reliable proxy of stock biomass, because they are often fishery independent and contain intensively collected biological data (HILBORN & WALTERS, 1992). However, as previously mentioned, stock assessments are only available for a small proportion of exploited stocks, which in the Mediterranean and the Black Sea is even smaller (LLEONART, 2005). In addition, stock assessment data are expensive to collect and time consuming to analyze, especially across trophic levels and habitats (they are usually confined to demersal stocks), when compared to the freely available official catch statistics. Thus, the immediate availability of catch records provides a first indication of change in stock biomass that can be later confirmed or rejected through a detailed stock assessment or survey.

The use of fisheries catch data and catch-based methods for evaluating the state of a fishery is important in the Mediterranean and the Black Sea for scientific and socio-economic reasons, as the area is bordered by over 25 countries, belonging to three continents, resulting to a multi-cultural puzzle with varying levels of fisheries technologies and management regulations (PAPACONSTANTINOU & FARRUGIO, 2000; LLEONART, 2005), but also to test environmental/climatic hypotheses (e.g. emigration of tropical species through Suez Canal: GOLANI, 1998). This multi-cultural puzzle imposes the use of common methodology that can be achieved through official catch statistics. Therefore, in the present work, the catch-based method of stock classification (FROESE & KESNER-REYES, 2002; KLEISNER *et al.*, 2012) was used in order to classify the Mediterranean and Black Sea stocks into exploitation categories, based on the relationship between the catch of a given year to the historical maximum catch. This method has been extensively used to assess the status of fisheries, globally or on ecosystem basis (WORM *et al.*, 2006; PAULY, 2008; ZELLER *et al.*, 2008; FROESE & KESNER-REYES, 2009) and is a reliable indicator of overexploitation especially when complemented with fishing effort and ecological indices (TSIKLIRAS *et al.*, 2013). Its disadvantage is that it does not account for species that are, even partly, not officially recorded (illegal, unreported, recreational and subsistence catches) but are affected by fishing; thus, the output of the method is a conservative estimate of the true stock condition because it refers to a portion of its catch.

The aim of the present work was to assess the exploitation status of the Mediterranean and Black Seas fisheries stocks for the period 1970-2010, using a catch-based method and compare them with the corresponding global trends (e.g. SUMAILA *et al.*, 2007) and/or similar work performed elsewhere (e.g. TSIKLIRAS *et al.*, 2013). The analysis was complemented with the temporal variability of the total catches, the number of recorded stocks, the mean trophic level of the catches, and the fishing-in-balance index.

MATERIALS AND METHODS

The annual catches, expressed as live weight equivalent of landings, have been routinely recorded since 1970, for the Mediterranean and the Black Sea combined (FAO area 37), by the General Fisheries Commission for the Mediterranean (GFCM: FAO, 2013). The Mediterranean and the Black Sea area has been further subdivided into four fishing subareas (western, central, eastern Mediterranean Sea and Black Sea) and ten fishing subdivisions (TSIKLIRAS *et al.*, 2010). The GFCM data refer to the legal and reported large- and small-scale fisheries catches, excluding discarded catch, illegal, unreported, recreational and sport fishing. For the present analysis, catch statistics of the Mediterranean and the Black Sea were extracted using FISHSTAT-J (FAO, 2013) from the GFCM Capture Production database for 2636 records (or stocks, defined as species-area-country combinations) for the period 1970-2010.

The annual status of fisheries (1970-2010) was classified into one of the following five categories: undeveloped, developing, fully exploited, overexploited, and depleted according to the catch-based stock classification method (FROESE & KESNER-REYES, 2002; KLEISNER *et al.*, 2012). The classification was based on the relationship between the catches (C_Y) of a given year (Y_C) compared to the year (Y_{Cmax}) of historical maximum catch (C_{MAX}). Thus, in an undeveloped fishery, $Y_C<Y_{Cmax}$ and $C_Y<0.1C_{MAX}$; in a developing fishery, $Y_C<Y_{Cmax}$ and $0.1C_{MAX}<C_Y<0.5C_{MAX}$; in a fully exploited fishery, $C_Y>0.5C_{MAX}$; in an overexploited fishery, $Y_C>Y_{Cmax}$ and $0.1C_{MAX}<C_Y<0.5C_{MAX}$; and, in a collapsed fishery, $Y_C>Y_{Cmax}$ and $C_Y<0.1C_{MAX}$. The former two categories (undeveloped and developing) were combined in the analysis, which included only the stocks with sufficient consecutive records. The analysis was separately performed to stocks that were present since 1970, i.e. those with 40 consecutive records.

Complementary to the catch-based classification, two trophodynamic indicators were also explored: the mean trophic level of the catches and the Fishing-in-Balance index. The mean weighted trophic level of the catch (mTLc) for each year (k), was calculated using the trophic levels of each species (taken from FishBase and SeaLifeBase: FROESE & PAULY, 2011; PALOMARES & PAULY, 2011), as (PAULY *et al.*, 1998):

$$mTLc = \frac{\sum_{i=1}^{m}(TL_i \times Y_{ik})}{\sum_{i=1}^{m} Y_{ik}}$$

where Y_i refers to the catches of a species (or group of species) i, and TL is the corresponding trophic level.

The fishing-in-balance index (FiB) of the catch for each year was calculated as follows (PAULY *et al.*, 2000):

$$FiB_k = \log[Y_k \times (\frac{1}{TE})^{mTLc_k}] - \log[Y_0 \times (\frac{1}{TE})^{mTLc_0}]$$

where Y refers to the total catches in year k, mTLc is the mean trophic level of the catches, TE is the mean energy-transfer efficiency between trophic levels that is assumed to be 0.1, and 0 refers to the first year in a time-series that is used as a baseline (in present dataset, 1970, the beginning of records, was set as a baseline). FiB attains a value of 0 for the first year of the series and remains rather stable when trophic level and catches change in opposite directions. Increasing FiB values indicate geographic or bathymetric expansion of fisheries, while decreasing FiB values indicate contraction (PAULY *et al.*, 2000).

Since the fishing effort was available for a very short period of time and consistently recorded as number of boats, engine horsepower and tonnage only for some countries of the Mediterranean Sea (LLEONART, 2005), it was not included in the analysis.

RESULTS

Number of stocks

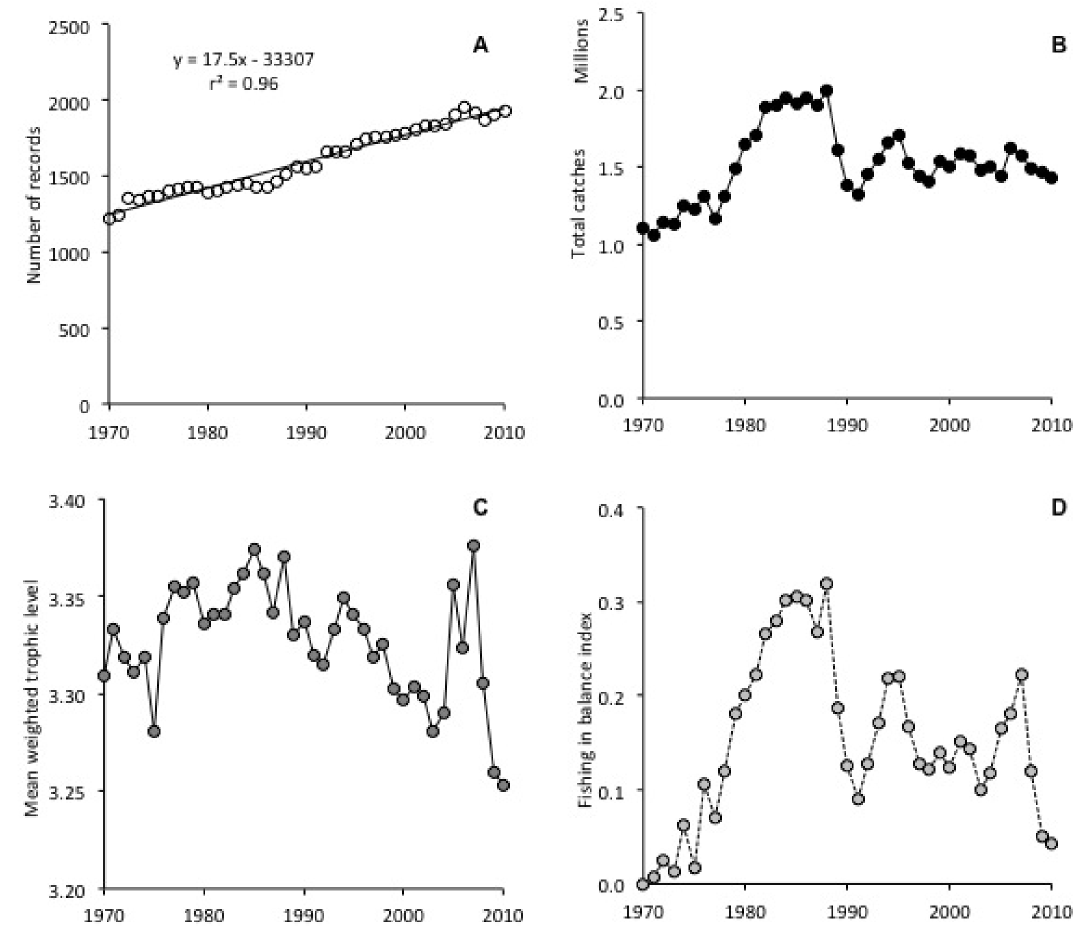
The number of recorded fisheries stocks in the Mediterranean and Black Sea increased linearly (r^2=0.96) from 1222 in 1970 to 1925 in 2010 (Fig. 1A). The rate of increase in stock records for the entire study period was around 18 records per year, i.e. the catches of 18 new stocks were being separately recorded each year.

Catches

Overall, the combined marine fisheries catches of fishes, crustaceans and cephalopods of the Mediterranean and the Black Sea ranged between 1.1×10^6 (in 1970) and 1.99×10^6 (in 1988) t. Since 1988, they declined by about 25% to 1.42×10^6 t in 2010. During the last decade the combined Mediterranean and Black Sea catches fluctuated around 1.5×10^6 t (Fig. 1B).

Trophodynamics

The mean weighted trophic level of the Mediterranean and Black Sea catches (mTLc)



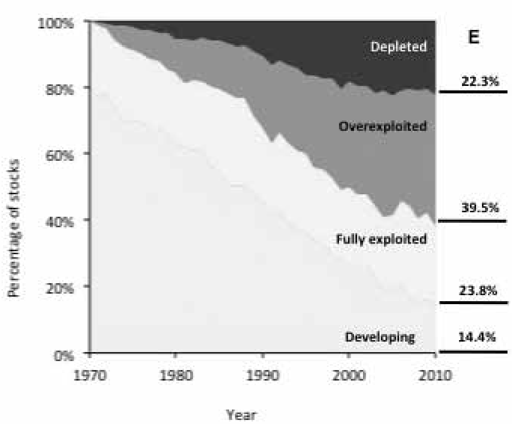


Fig. 1. Basic trends of the Mediterranean and Black Sea fisheries for the period 1970 to 2010. The number of stocks recorded by GFCM Capture Production per year (A), the combined marine catches of fishes, crustacean and cephalopods (B), the mean trophic level (mTLc) of the catches (C), the Fishing-in-Balance (FiB) index (D) and the trend in the status of fisheries resources according to the catch-based method (FROESE & KESNER-REYES, 2002) and the official FAO-GFCM statistics (E).

fluctuated between 3.28 (in 1975 and 2003) and 3.38 (in 2007), with a value of 3.25 in 2010 (Fig. 1C). Overall, mTLc decreased from an average value (±SD) of 3.33 (±0.024) for 1970-1979 to an average value (±SD) of 3.30 (±0.038) for 2001-2010, thus confirming that the Mediterranean and Black Sea food webs have been fished down. The tendency of mTLc is declining since 1988, with three outlying values compared to the overall declining trend (2005, 2006, 2007). The declining rate of mTLc was 0.02 per decade for 1990-2010.

The fishing-in-balance index increased rapidly from 1970 (FiB=0, baseline) to a maximum value of 0.318 in 1988 and then declined sharply to 0.089 in 1991 (Fig. 1C). Since then, FiB fluctuated around 0.15 with a mean value of 0.13±0.055 for the last decade (Fig. 1D).

Stock classification

Based on the historically maximum catch, which varied among the Mediterranean and Black Sea stocks included in the analysis, in 2010, out of the 1798 available stocks, 400 (22.3%) were depleted, 711 (39.5%) were overexploited, 428 (23.8%) were fully exploited and 259 (14.4%) were developing (Fig. 1E). In the early 1970s, the majority of stocks had been largely underexploited and most fisheries (over 75%) were developing (Fig. 1E). Only a few stocks were overexploited and even fewer were depleted. Over the last 20 years, however, an increasing percentage (averaging 35.8% for 2001-2010) of stocks suffers from overexploitation. The cumulative percentage of overfished and crashed stocks rapidly increased from 10% in 1976, to 20% in 1984, 30% in 1989, 40% in 1995, 50% in 1999 and around 60% in 2004. In contrast, the percentage of developing stocks declined dramatically, from around 80% in 1970 to 14.4% in 2010. Interestingly enough, the percentage of fully exploited stocks has remained rather unchanged since 1970 (averaging 22.9±2.15% for 1970-2010).

Generally, in 2010, most Mediterranean and Black Sea stocks belonging to large-bodied species were overexploited or depleted (data not shown), irrespectively of their habitat preferences (i.e., pelagic, demersal or reef-associated). For example, the majority of large pelagic (e.g. garfish *Belone belone*), demersal (e.g. European hake *Merluccius merluccius*), and reef-associated (e.g. dusky grouper *Epinephelus marginatus*) stocks were overexploited/depleted. However, there were some medium- (e.g. blue whiting *Micromesistius poutassou*, common dentex *Dentex dentex*) and small-sized taxa (e.g. bogue *Boops boops*, the picarels *Spicara* spp.) that were also overexploited irrespectively of their habitat (data not shown).

When the analysis was performed to stocks that had been recorded since 1970 (i.e. with 40 consecutive records), in 2010, more stocks were depleted (27.2%) and overexploited (51.5%) compared to fully exploited (17.0%) and developing (4.3%).

DISCUSSION

The increasing number of recorded stocks with time (Fig. 1A) indicates either the exploitation of new species, or the separate recording of catches of species that had been previously recorded aggregated to higher taxonomic levels. In any case, the increasing number of records with time artificially increases the contribution of developing stocks in the analysis, thereby reducing the remaining categories. Thus, some developing stocks may well have been fully exploited or even overfished based on their previous catches that were reported aggregated. The separate analysis on the stocks with 40 consecutive records confirms the bias towards developing stocks.

The total Mediterranean and Black Sea catches were increasing from 1970, peaked in 1985-1988 and since then, they have declined by 25% and remained rather constant since late 1990s (Fig. 1B). This decline coincides with the slow, albeit steady, declining rates of the mean trophic level of the catches, which also occurred after the mid 1980s (Fig. 1C). Since the decline in trophic level occurs at low rates (also reported by PAULY *et al.*, 1998, but based on a longer time series, that of Global Capture Production for FAO Area 37: FAO, 2011), then the fishing-in-balance (FiB) index is determined by the fluctuation of catches (PAULY *et al.*, 2000). Hence, their similar pattern of decline is a clear sign of fisheries contraction in the Mediterranean and the Black Sea (PAULY *et al.*, 2000; TSIKLIRAS *et al.*, 2013). The Mediterranean and the Black Sea stock analysis in the present work was combined merely for comparability purposes, but, given the different environmental and fishing properties of these two seas (FAO, 1997; DASKALOV, 2002), a further investigation of their fisheries status may be necessary on a subarea or even subdivision basis. The irregular values of 2005, 2006 and 2007 are the result of variable taxonomic aggregation in various areas (e.g. Libya, Montenegro) and catch fluctuations of the small pelagic fishes (anchovy, sardine and round sardinella) in the central Mediterranean and the Black Sea. These irregularities were also apparent in the stock classification to exploitation categories (Fig. 1E).

Previous research on the exploitation status of Mediterranean and Black Sea fisheries stocks report that, in the Mediterranean, 78% of the stocks are fully exploited, whereas the 85% of the stocks are overexploited in the Black Sea (DASKALOV, 2002; SHERMAN & ADAMS, 2010). According to another report, 60% of the Mediterranean and Black Sea stocks were fully exploited during 1951-1960, but soon recovered (FROESE & KESNER-REYES, 2002). The remaining 40% had been overfished by that time but never fully recovered in the following 30 years (FROESE & KESNER-REYES, 2002). Similar research using the catch-based method but applied on a different dataset (that of Global Capture Production for FAO Area 37, which extends back to 1950, instead of GFCM Capture Production for the Mediterranean, which extends back to 1970: FAO, 2013) reports that over 80% of the Mediterranean stocks are fully exploited, but only a few are depleted (AQUARONE *et al.*, 2008). The situation is even worst for the Black Sea, where around 90% of the stocks have been reported as collapsed for 2004 (HEILEMAN *et al.*, 2008, using the FAO Global captured production). Finally, a recent work on the Greek fisheries showed that, in 2007, 65% of them were overfished and 32% were fully exploited (TSIKLIRAS *et al.*, 2013). No depleted stocks were observed in the Greek waters and only 3% of them were developing. Overexploitation of Greek marine fisheries resources has been reported to occur across taxa, sizes and habitats, with several small-bodied species being overfished (TSIKLIRAS *et al.*, 2013).

Life-history theory predicts that large-bodied, long-lived and slow growing species are more susceptible to overexploitation (ADAMS, 1980; FROESE & KESNER-REYES, 2002). Indeed, most demersal and reef-associated Mediterranean and Black Sea stocks, i.e. those characterized by slow life-history strategies, were among the most heavily exploited across the study area, a trend that is supported by theoretical and empirical data (JENNINGS *et al.*, 1998; REYNOLDS *et al.*, 2005). Almost all stocks of European hake *Merluccius merluccius*, dusky grouper *Epinephelus marginatus* and common dentex *Dentex dentex* were either depleted or overexploited, a state that also emerged for some of them through their detailed stock assessments (LLEONART, 2005). The intensive and selective removal of species with slow life-history strategies by fishing may reduce biodiversity, both within and among species, and affect the ecosystem structure and functioning (PAULY *et al.*, 1998; BIRKELAND & DAYTON, 2005), i.e., may lead to ecosystem overfishing (MURAWSKI, 2000). The stocks of large pelagic fishes, such as those of the bluefin tuna *Thunnus thynnus* and swordfish *Xiphias gladius*, have also been reported as overexploited (LLEONART, 2005), but because they are subjected to Total Allowable Catch regulations, they cannot be classified based on their catches and were excluded from the analysis.

The variability in catches of small pelagic fishes may be related to their complex interrelationships (e.g. the anchovy/sardine complex: KATARA *et al.*, 2011), which, in turn, may be the result of environmental or climatic forces on their distribution and abundance (e.g. round sardinella *Sardinella aurita*: TSIKLIRAS, 2008). Thus, when fishing effort data are not available and detailed knowledge of the stock dynamics is lacking, it is difficult to disentangle the climatic and fishing effects and the interpretation of such cases should be cautious (ZWOLINKSI & DEMER, 2012). Besides small pelagic fishes, the overexploitation status of demersal medium- and small-sized species shows that fishing gradually penetrates to lower trophic levels either directly, by targeting smaller ones (STERGIOU & TSIKLIRAS, 2011; TSIKLIRAS *et al.*, 2013), or indirectly by by-catching them. However, by-catch biomass removal cannot be easily quantified from catch statistics, or from stock assessments.

In order to reverse overexploitation trends in the Mediterranean and the Black Seas, near future fisheries management scenarios should focus on the preservation of ecosystem health by strictly enforcing current regulations, limiting fishing effort, banning excessive subsidies, and excluding a large part of current fishing grounds from any fishing activity (PAULY *et al.*, 2002).

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Trendovi iskorištavanja živih bogatstava Sredozemnog i Crnog mora

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Trendovi iskorištavanja živih bogatstava Sredozemnog i Crnog mora su analizirani pomoću ukupnih godišnjih ulova, varijabilnosti prosječne trofičke razine ulova te uravnoteženosti ribolovnog indeksa za razdoblje 1970.-2010. U kasnim 1980-im ukupni ulov se naglo povećao do svoje maksimalne moguće razine, a zatim je došlo do pada te je ostao prilično stabilan na razini od oko 75% od svoje najveće razine. Prosječne trofičke razine ulova slijede sličan obrazac ukupnih ulova s konstantnim (osim za razdoblje 2005.-2007.) i stalnim padom od kraja 1980-ih godina. Godišnji ulovi 2636 iskorištavanih stockova također su analizirani za razdoblje od 1970. do 2010. godine i podijeljeni prema eksploatacijskim kategorijama. U 2010. godini oko 22% zaliha živih bogatstava je bilo iscrpljeno, 40% se prekomjerno iskorištavalo, a 24% je doseglo maksimalnu razinu iskorištavanja. Sve analize upućuju na to da je iskorištavanje živih bogatstava Sredozemnog i Crnog mora doseglo maksimalne vrijednosti, pa čak u nekim slučajevima i do neodržive razine.

Ključne riječi: ulov, živa bogatstva, dinamika trofičkih odnosa, prelov, Sredozemno more, Crno more